A SYNOPSIS OF AN EXPANDED *SOLMS-LAUBACHIA* (BRASSICACEAE), AND THE DESCRIPTION OF FOUR NEW SPECIES FROM WESTERN CHINA[1]

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ABSTRACT

Sequence data from the nuclear ribosomal ITS region and the chloroplast *trnL-F* were used to examine the generic delimitations of *Solms-laubachia* Muschl., *Christolea* Cambess., *Desideria* Pamp., *Leiospora* (C. A. Mey.) F. Dvořák, and *Phaeonychium* O. E. Schulz. *Solms-laubachia*, *Desideria*, and *P. jafrii* Al-Shehbaz formed a well-supported monophyletic clade, with *Christolea* as sister group. However, both *Solms-laubachia* and *Desideria* were polyphyletic, as they appeared in more than two positions in that clade, within which *P. jafrii* was embedded. The results are consistent with those based on sequences of plastid maturase (*matK*) and the nuclear chalcone synthase (*Chs*). SEM survey further reveals that the seed epidermis micromorphology of *D. baiogoinensis* (K. C. Kuan & C. H. An) Al-Shehbaz is most similar to that of *S. lanata* Botsch. Based on these findings, a comprehensive synopsis of an expanded *Solms-laubachia* with 26 species is presented; all species of *Desideria* and *P. jafrii* are transferred to *Solms-laubachia* resulting in 12 new combinations: *S. baiogoinensis* (K. C. Kuan & C. H. An) J. P. Yue, Al-Shehbaz & H. Sun, *S. flabellata* (Regel) J. P. Yue, Al-Shehbaz & H. Sun, *S. haranensis* (Al-Shehbaz) J. P. Yue, Al-Shehbaz & H. Sun, *S. himalayensis* (Cambess.) J. P. Yue, Al-Shehbaz & H. Sun, *S. incana* (Ovcz.) J. P. Yue, Al-Shehbaz & H. Sun, *S. jafrii* (Al-Shehbaz) J. P. Yue, Al-Shehbaz & H. Sun, *S. linearis* (N. Busch) J. P. Yue, Al-Shehbaz & H. Sun, *S. mieheorum* (Al-Shehbaz) J. P. Yue, Al-Shehbaz & H. Sun, *S. mirabilis* (Pamp.) J. P. Yue, Al-Shehbaz & H. Sun, *S. nepalensis* (H. Hara) J. P. Yue, Al-Shehbaz & H. Sun, *S. prolifera* (Maxim.) J. P. Yue, Al-Shehbaz & H. Sun, and *S. stewartii* (T. Anderson) J. P. Yue, Al-Shehbaz & H. Sun. Furthermore, four new species of *Solms-laubachia* are described from western China: *S. angustifolia* J. P. Yue, Al-Shehbaz & H. Sun, *S. grandiflora* J. P. Yue, Al-Shehbaz & H. Sun, and *S. sunhangiana* J. P. Yue & Al-Shehbaz (all from Sichuan Province), and *S. calcicola* J. P. Yue, Al-Shehbaz & H. Sun (from Xizang). Both *S. linearifolia* (W. W. Sm.) O. E. Schulz and *S. mirabilis* are lectotypified.

Key words: Brassicaceae, China, *Christolea*, *Desideria*, *Leiospora*, ITS, IUCN Red List, *Phaeonychium*, *Solms-laubachia*, *trnL-F*.

Solms-laubachia Muschl. (Brassicaceae) is a Sino-Himalayan endemic genus characterized by the perennial habit, entire leaves, trichomes absent or simple, latiseptate fruits detached at maturity from the pedicel, entire capitate stigmas, and rounded replum concealed by the strongly angled valve margins (Lan & Cheo, 1981; Al-Shehbaz & Yang, 2001). Except for *S. platycarpa* (Hook. f. & Thomson) Botsch., which also occurs in Bhutan and Sikkim, the other eight species previously described in the genus are highly restricted to the alpine areas of northwestern Yunnan, western Sichuan, and eastern Tibet, where they grow

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[1] Portions of this paper are taken from a thesis entitled "Phylogeny of the genus *Solms-laubachia* (Brassicaceae)" and submitted by the first author in partial fulfillment of a doctorate degree to the Department of Phytogeography and Ecology of Kunming Institute of Botany, Chinese Academy of Sciences. The new species were collected during field investigations in the Hengduan Mountain region of China, with support from the U.S. National Science Foundation (grant no. DEB-0321846 to David E. Boufford) and the National Natural Science Foundation of China (grant nos. 30625004, 40332021, 40771073, and 30420120049 to H. Sun). Lab work was partially supported by the Innovation Project of the Chinese Academy of Sciences (KSCX2-YW-Z-030) and a Mercer Fellowship from the Arnold Arboretum to J. P. Yue. Fieldwork in Xinjiang by I. Al-Shehbaz was supported by the National Geographic Society (grant 7405-03). We thank Jason R. Grant for providing DNA of three accessions of *Desideria* and one of *Leiospora*. We are grateful to Victoria C. Hollowell, Beth Parada, and Allison Brock for their editorial advice, to Barbara Neuffer and Karol Marhold for their critical reviews of the manuscript, and to Fred Keusenkothen for lettering the seed figures. Last, but certainly not least, we thank the directors and curators of the herbaria cited.

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doi: 10.3417/2006214

ANN. MISSOURI BOT. GARD. 95: 520–538. PUBLISHED ON 23 SEPTEMBER 2008.

on scree slopes and in rock crevices (Lan & Cheo, 1981; Al-Shehbaz & Yang, 2001).

Solms-laubachia was placed by Schulz (1936) in the tribe Matthioleae, a disposition followed by several Chinese taxonomists (e.g., Kuan, 1985; Lan, 1987; An, 1995; Li, 1995; Huang, 1997; Tan et al., 1999). However, Schulz's tribal classification of the Brassicaceae has been considered as highly artificial (Hedge, 1976; Al-Shehbaz, 1984; Koch et al., 2003; Mitchell-Olds et al., 2005; Al-Shehbaz et al., 2006). Janchen (1942) united the Matthioleae with the Hesperideae, a position followed by Al-Shehbaz (1984) who adopted the earlier tribal name Anchonieae and further suggested the exclusion of *Solms-laubachia* and other genera from the combined tribe (Al-Shehbaz, 1988). In their broadly sampled molecular phylogenetic study on the Brassicaceae, Beilstein et al. (2006) showed that *Solms-laubachia* (with *S. zhongdianensis* J. P. Yue, Al-Shehbaz & H. Sun as the representative) falls within a well-supported monophyletic clade containing species of *Braya* Sternb. & Hoppe, *Desideria* Pamp., *Euclidium* W. T. Aiton, *Malcolmia* W. T. Aiton, *Neotorularia* Hedge & J. Léonard, *Sisymbriopsis* Botsch. & Tzvelev, *Rhammatophyllum* O. E. Schulz, *Shangrilaia* Al-Shehbaz, J. P. Yue & H. Sun, and *Tetracme* Bunge. Based on the molecular results and morphological evidence, Al-Shehbaz et al. (2006) tentatively assigned these 10 genera and 15 others within the tribe Euclidieae. However, the generic delimitation within this tribe needs further study since some genera (e.g., *Neotorularia*, *Sisymbriopsis*) have been shown to be polyphyletic (Warwick et al., 2004, 2007).

Yue et al. (2006) used sequences of the nuclear chalcone synthase (*Chs*) and plastid maturase (*matK*) to study the phylogenetic relationships of *Solms-laubachia* within the Brassicaceae. They found that the four *Desideria* species, *D. baiogoinensis* (K. C. Kuan & C. H. An) Al-Shehbaz, *D. himalayensis* (Cambess.) Al-Shehbaz, *D. linearis* (N. Busch) Al-Shehbaz, and *D. stewartii* (T. Anderson) Al-Shehbaz, as well as *Phaeonychium jafrii* Al-Shehbaz were nested within *Solms-laubachia* in a well-supported clade. Therefore, their data support an expanded *Solms-laubachia*, including *Desideria* and *P. jafrii*. The present paper aims to further test the relationships of *Solms-laubachia*, *Desideria*, and *P. jafrii* using sequences of the nuclear ribosomal ITS and the chloroplast non-coding *trnL-F* region. Additionally, seed epidermis of 13 *Solms-laubachia* species was surveyed under SEM. Finally, a comprehensive synopsis of *Solms-laubachia* is presented in this paper based on the molecular and morphological data.

MATERIALS AND METHODS

PLANT MATERIAL

Plant material used in this study is listed in Table 1. The ITS sequences were obtained from 19 species (22 accessions), including 13 of *Solms-laubachia* (17 accessions, including four new species), two species of *Desideria*, one species of *Christolea* Cambess., one accession each of *Leiospora pamirica* (Botsch. & Vved.) Botsch. & Pachom. and *Phaeonychium jafrii*. Published ITS sequences of *D. incana* (Ovcz.) Al-Shehbaz and *D. prolifera* (Maxim.) Al-Shehbaz were also included in the analyses (Table 1). The *trnL-F* sequences were obtained from 21 species (24 accessions), including 12 species of *Solms-laubachia* (16 accessions), four species of *Desideria* (five accessions), one accession of *P. jafrii*, one species of *Christolea*, and two species of *Leiospora* (C. A. Mey.) F. Dvořák. *Leiospora* species were chosen as outgroups because this genus was sister to the clade containing species of *Christolea*, *Solms-laubachia*, *Desideria*, and *Phaeonychium* O. E. Schulz (Yue et al., 2006). Taxa whose seeds were observed under SEM are listed in Table 1 and marked with an asterisk.

DNA EXTRACTION, PCR, AND SEQUENCING

Total genomic DNAs were extracted from silica gel–dried leaves using a Qiagen DNeasy Plant Mini Kit (Santa Clarita, California, U.S.A) following the manufacturer's protocol. Genomic DNA from three accessions of *Desideria* and one of *Leiospora* were kindly provided by Jason R. Grant (Université de Neuchâtel, Switzerland).

Nuclear ribosomal DNA ITS. The nuclear ribosomal DNA (nrDNA) ITS region was amplified using primers ITS-4 of White et al. (1990) and ITS-leu of Baum et al. (1998). A 25-μl polymerase chain reaction (PCR) included 2.5 μl of 10× Taq polymerase buffer, 4 μl of dNTP (2.5 mM), 3 μl of $MgCl_2$ (25 mM), 1 μl of each primer (10 μM), 0.3 μl of Taq polymerase (5 units/μl), 2 μl of dimethyl sulfoxide (DMSO), and 20–50 ng DNA. The PCR program included a 3-min. hotstart and 34 cycles followed by an additional 10 min. at 72°C. Each cycle consisted of 45 sec. denaturing at 94°C, 70 sec. annealing at 55°C–57°C, and a 1-min. extension at 72°C. PCR products were gel-purified using a Qiagen Gel Purification Kit, following the manufacturer's protocol. For sequencing, the same primers as for PCR were used; for some taxa, ITS-2 and ITS-3 of White et al. (1990) were used as well.

Table 1. Vouchers and sources of species used in this study. An asterisk (*) indicates the taxa also studied for seed epidermis under SEM. Dagger symbol (†) indicates sequence obtained from the GenBank database.

Taxon and accession	Voucher	Source	ITS	*trnL-F*
**Solms-laubachia angustifolia* J. P. Yue, Al-Shehbaz & H. Sun	*Yue 0250* (KUN)	China, Sichuan, Daocheng	DQ523420	DQ523319
**Solms-laubachia baiogoinensis* (K. C. Kuan & C. H. An) J. P. Yue, Al-Shehbaz & H. Sun [= *Desideria baiogoinensis*]	*Yue 0246* (KUN)	China,Tibet, Mozhugongka	DQ523416	DQ523315
**Solms-laubachia calcicola* J. P. Yue, Al-Shehbaz & H. Sun	*Boufford et al. 31975* (A)	China, Tibet, Riwoqe	DQ523421	DQ523320
**Solms-laubachia eurycarpa* (Maxim.) Botsch., 1	*Yue 0249* (KUN)	China, Sichuan, Yading	DQ523404	DQ523303
Solms-laubachia eurycarpa (Maxim.) Botsch., 2	*Yue 0158* (KUN)	China, Yunnan, Deqing	DQ523405	DQ523304
**Solms-laubachia grandiflora* J. P. Yue, Al-Shehbaz & H. Sun	*Boufford et al. 30727* (A)	China, Sichuan, Xiangcheng	DQ523419	DQ523318
Solms-laubachia himalayensis (Cambess.) J. P. Yue, Al-Shehbaz & H. Sun [= *Desideria himalayensis*]	*McBenth 1486* (E)	Nepal	–	DQ523327
Solms-laubachia incana (Ovcz.) J. P. Yue, Al-Shehbaz & H. Sun [= *Desideria incana*]	–		†AJ628335	
Solms-laubachia jafrii (Al-Shehbaz) J. P. Yue, Al-Shehbaz & H. Sun [= *Phaeonychium jafrii*]	*Yue 0233* (KUN)	China, Tibet, Lhasa	DQ523422	DQ523321
**Solms-laubachia lanata* Botsch., 1	*Yue 0234* (KUN)	China, Tibet, Lhasa	DQ523409	DQ523308
Solms-laubachia lanata Botsch., 2	*Yue 0237* (KUN)	China, Tibet, Lhasa	DQ523410	DQ523309
**Solms-laubachia linearifolia* (W. W. Sm.) O. E. Schulz	*Yue 0157* (KUN)	China, Yunnan, Deqing	DQ523414	DQ523313
Solms-laubachia linearis (N. Busch) J. P. Yue, Al-Shehbaz & H. Sun, 1 [= *Desideria linearis*]	*Bartholomew et al. 9549* (MO)	China, Xinjiang	DQ523417	DQ523316
Solms-laubachia linearis (N. Busch) J. P. Yue, Al-Shehbaz & H. Sun, 2 [= *Desideria linearis*]	*Stainton 3055* (E)	Pakistan		DQ523329
**Solms-laubachia minor* Hand.-Mazz.	*Yue 0379* (KUN)	China, Sichuan, Yanyuan	DQ523418	DQ523317
**Solms-laubachia platycarpa* (Hook. f. & Thomson) Botsch., 1	*Yue 0238* (KUN)	China, Tibet, Dangxion	DQ523408	DQ523307
Solms-laubachia platycarpa (Hook. f. & Thomson) Botsch., 2	*Yue 0239* (KUN)	China, Tibet, Dangxion	DQ523407	DQ523306
Solms-laubachia prolifera (Maxim.) J. P. Yue, Al-Shehbaz & H. Sun [= *Desideria prolifera*]		–	†AJ628333	–
**Solms-laubachia pulcherrima* Muschl.	*Yue 0153* (KUN)	China, Yunnan, Lijian	DQ523411	DQ523310
**Solms-laubachia retropilosa* Botsch., 1	*Yue 0162* (KUN)	China, Sichuan, Xiancheng	DQ523413	DQ523312
Solms-laubachia retropilosa Botsch., 2	*Yue 0246* (KUN)	China, Tibet, Zuogong	DQ523412	DQ523311
Solms-laubachia stewartii (T. Anderson) J. P. Yue, Al-Shehbaz & H. Sun [= *Desideria stewartii*]	*McBeath 2105* (E)	India		DQ523328
Solms-laubachia sunhangiana J. P. Yue & Al-Shehbaz	*Boufford et al. 33464* (A)	China, Sichuan, Jiulong	EU186027	–
**Solms-laubachia xerophyta* (W. W. Sm.) H. F. Comber	*Yue 0251* (KUN)	China, Yunnan, Zhongdian	DQ523406	DQ523305
**Solms-laubachia zhongdianenis* J. P. Yue, Al-Shehbaz & H. Sun	*Yue 0156* (KUN)	China, Yunnan, Zhongdian	DQ523415	DQ523314
Outgroup taxa				
Christolea crassifolia Cambess.	*Bartholomew et al. 9499* (MO)	China, Xinjiang	DQ523423	DQ523322
Leiospora exscapa (C. A. Mey.) F. Dvořák	*Murray et al. 457* (ALA)	Russia	–	DQ523330
Leiospora pamirica (Botsch. & Vved.) Botsch. & Pachom.	*Bartholomew et al. 9790* (MO)	China, Xinjiang	DQ523424	DQ523323

Plastid trnL-F. The primer pair c and f of Taberlet et al. (1991) was used to amplify the *trnL* intron and the *trnL-trnF* intergenic spacer. A 50-μl PCR reaction included 50–100 ng DNA, 5 μl of 10× Taq polymerase buffer, 4 μl of dNTP (2.5 mM), 4 μl of $MgCl_2$ (25 mM), 2 μl of each primer (10 μM), and 0.5 μl of Taq polymerase (5 units/μl). The PCR profile used to amplify the *trnL-F* region included a 3-min. hotstart and 34 cycles (94°C for 1 min., 55°C for 1 min., 72°C for 2 min.), and a final extension at 72°C for 7 min. PCR products were purified using the method described above. Sequencing of the region was done using the PCR primers as well as primers d and e of Taberlet et al. (1991).

Sequences were analyzed using an automated ABI Genetic Analyzer 3100 (GMI, Inc., Ramsey, Minnesota, U.S.A.), then edited using Sequencher (version 3.0, Gene Codes Corp., Inc., Ann Arbor, Michigan, U.S.A.), and then aligned using ClustalX version 1.83 (PC version) (Thompson et al., 1997), followed by manual adjustments.

PHYLOGENETIC ANALYSES

Phylogenetic analyses were performed for the data sets using maximum parsimony (MP) (Farris et al., 1970; Fitch, 1971). The heuristic searches for MP analysis were conducted using PAUP 4.0b10 (Swofford, 2002) with the following conditions: random sequence addition with 1000 replicates and 10 trees held at each step, tree bisection-reconnection (TBR) branch swapping, MULPARS on, and the steepest descent off. Character state changes were unordered and equally weighted in the analysis. Gaps were treated as missing data. Indels in the *trnL-F* alignment were coded following Simmons and Ochoterena (2000). Bootstrap (BS) and jackknife analyses of 1000 replicates were performed respectively to estimate the support for individual clades using heuristic tree search options as in the MP analyses.

It was not possible to obtain the ITS sequences for *Desideria himalayensis*, *D. stewartii*, *D. linearis*, and *Leiospora exscapa* (C. A. Mey.) F. Dvořák, nor produce the *trnL-F* sequences for *D. prolifera*, *D. incana*, and *Solms-laubachia sunhangiana* J. P. Yue & Al-Shehbaz. Except for these seven species, the ITS and *trnL-F* sequences of all other exemplar taxa were combined into a data set, and the incongruence length difference (ILD) test (Farris et al., 1994, as implemented in PAUP) was used to assess potential conflicts between the phylogenetic signals from the two different DNA data sets. For that test, 1000 replicates were analyzed with a heuristic search, each with 10 random sequence addition replicates. To ensure the accuracy of the *P* value in the ILD test, only parsimony informative positions were used.

SEED EPIDERMIS

Seeds of each species were mounted on aluminum stubs using double-sided adhesive and sputter-coated with gold-palladium. Observations were made using a KYKY-10000B (Science Instrument Company, Beijing, China) electronic microscope at 15 kV. Descriptive terminology of seed-coat epidermis follows Murley (1951).

RESULTS AND DISCUSSION

ITS SEQUENCE DATA

Twenty-four sequences of the ITS region, including the 5.8S gene, were used in the analysis (Table 1). The multiple alignment of the ITS region produced a data set of 622 bp, of which 514 bp were uninformative, 65 bp were variable but not parsimony informative, and only 43 bp were potentially parsimony informative. The ITS-1 region was variable at 59 of the 277 sites (21.3%), the ITS-2 was variable at 45 of the 221 sites (20.4%), and the 5.8S gene was variable at only 4 of the 124 sites (3.2%).

The sequences were similar in length, and the alignment only required six indels with one, two, or three bp. ITS sequence divergence ranged from 5.7%–9.2% between the ingroup and outgroup and 0%–7.5% within the ingroup. The sequences of two accessions of *Solms-laubachia lanata* Botsch. were identical, and those of the single accessions of *S. calcicola* J. P. Yue, Al-Shehbaz & H. Sun and *S. sunhangiana* were indistinguishable.

The MP analysis yielded three most parsimonious trees (MPTs) of 150 steps (confidence interval [CI] = 0.82, retention index [RI] = 0.77, and rescaled consistency index [RC] = 0.63) (Fig. 1). All sampled species of *Solms-laubachia*, *Desideria*, and *Phaeonychium jafrii* formed a monophyletic clade with 98% BS support. Within this clade, *D. linearis* was basal to the remaining taxa. Eleven species of *Solms-laubachia* formed a core clade with 71% BS support. Within core *Solms-laubachia*, two accessions of *S. retropilosa* Botsch. and one of *S. linearifolia* (W. W. Sm.) O. E. Schulz lay basal to a weakly supported (51%) clade that consisted of three groups, with weak support. *Desideria prolifera* was basal to core *Solms-laubachia*, whereas *D. incana* and *P. jafrii* were basal to these other species, but with weak support.

TRNL-F SEQUENCE DATA

Twenty-five accessions were included in the analysis (Table 1). The multiple alignment of the

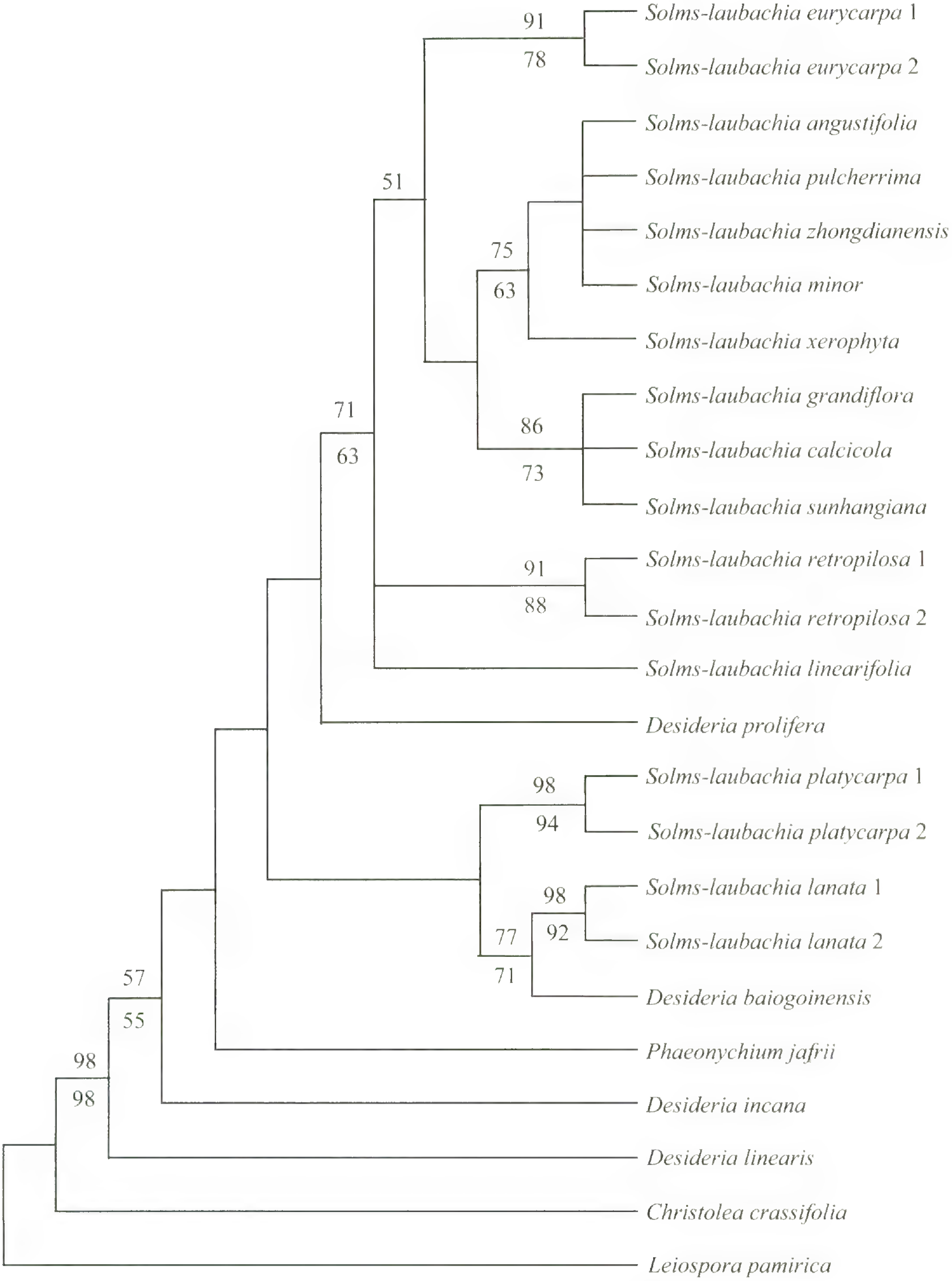
91
78
Solms-laubachia eurycarpa 1
Solms-laubachia eurycarpa 2
Solms-laubachia angustifolia
Solms-laubachia pulcherrima
51
Solms-laubachia zhongdianensis
75
63
Solms-laubachia minor
Solms-laubachia xerophyta
Solms-laubachia grandiflora
71
63
86
73
Solms-laubachia calcicola
Solms-laubachia sunhangiana
91
88
Solms-laubachia retropilosa 1
Solms-laubachia retropilosa 2
Solms-laubachia linearifolia
Desideria prolifera
98
94
Solms-laubachia platycarpa 1
Solms-laubachia platycarpa 2
98
92
Solms-laubachia lanata 1
Solms-laubachia lanata 2
77
71
Desideria baiogoinensis
57
55
Phaeonychium jafrii
98
98
Desideria incana
Desideria linearis
Christolea crassifolia
Leiospora pamirica

Figure 1. Strict consensus tree of three MPTs based on ITS sequence. Numbers above and below branches are BS and jackknife percentages (values lower than 50% not shown).

trnL-F region required 42 indels. The data set had 1106 characters. However, a segment of 64 bp (bp 302–365) was excluded because of ambiguous sequence alignment. Of the remaining 1042 characters, 885 were uninformative, 75 were variable but not parsimony informative, and 82 were potentially parsimony informative.

The *trnL-F* sequence divergence ranged from 3.4%–5.0% between the ingroup and outgroup and 0%–3.3% within the ingroup. Identical sequences were detected between two conspecific accessions of *Solms-laubachia platycarpa*.

The MP analysis yielded 2565 MPTs of 193 steps (CI = 0.84, RI = 0.81, and RC = 0.68; cf. Fig. 2). Twelve *Solms-laubachia* species, together with the four *Desideria* species and *Phaeonychium jafrii*, formed a monophyletic clade, with *Christolea crassifolia* Cambess. as sister group with 100% BS support. Within this, *Desideria himalayensis* and *D. stewartii* formed a basal clade with 91% BS support. The remaining species formed less resolved polytomy with only 58% bootstrap support. The two accessions of *S. lanata* were grouped with *S. angustifolia* J. P. Yue, Al-Shehbaz & H. Sun at 60% BS support, while *D. baiogoinensis* occupied a solitary position in the *Solms-laubachia* polytomy.

COMBINED SEQUENCE DATA

The ILD test returned a *P* value of 0.014, which is lower than the general threshold of 0.05 (Farris et al., 1995). However, Sullivan (1996) argued that the significance threshold of 0.05 may be too conservative for the ILD test. Cunningham (1997) pointed out that combining data improved or did not reduce phylogenetic accuracy whenever a *P* value from the ILD test was greater than 0.01. Therefore, we performed an analysis on the combined data set.

The combined data set consists of 1664 characters, among which 1419 were uninformative, 146 were variable but not parsimony informative, and 99 were potentially parsimony informative. Phylogenetic analysis of the combined data set yielded two MPTs of 324 steps (CI = 0.81, RI = 0.74, and RC = 0.57), which have a topology nearly identical to the ITS tree, differing only in the position of *Desideria baiogoinensis* (not shown). In the combined tree, *D. baiogoinensis* clustered with *Solms-laubachia platycarpa* rather than immediately with *S. lanata* as in the ITS strict consensus. However, no relationships received convincing support. With the exception of the basal position of *D. linearis*, which received 84% BS support, the relationships among other ingroups were not convincingly resolved in the combined analysis.

Both ITS and *trnL-F* sequence data revealed that *Solms-laubachia*, *Desideria*, and *Phaeonychium jafrii* formed a monophyletic clade (Figs. 1, 2). However, neither *Solms-laubachia* nor *Desideria* is monophyletic, appearing in more than two positions within the core clade. Therefore, sequences of the ITS and *trnL-F* results support an expanded *Solms-laubachia* that includes *Desideria* and *P. jafrii*, as suggested by Yue et al. (2006). However, neither the separate nor combined analysis could resolve their terminal relationship convincingly. The present study shows rather low-level sequence divergences of ITS (from 0%–5.1%; mean 2.4%) and *trnL-F* (0%–2.6%; mean 1.33%) among *Solms-laubachia* and *Desideria*.

Comparisons of the phylogenetic trees generated from the ITS (Fig. 1) and the *trnL-F* (Fig. 2) showed some discrepancies for the position of a few taxa on either tree. For example, in the ITS tree *Desideria linearis* was basal to all other ingroup taxa, whereas in the *trnL-F* tree it was embedded in a weakly supported polytomy. *Solms-laubachia lanata* formed a sister group with *D. baiogoinensis* in the ITS phylogeny (77% BS), but switched its sister group relationship to *S. angustifolia* (60% BS) in the *trnL-F* phylogeny. These discordances between nuclear and chloroplast trees may give some clues for exploring speciation mechanisms within *Solms-laubachia*. The species with such conflicting relationships between the ITS and *trnL-F* trees might be the result of hybrid speciation followed by inheritance of chloroplast DNA from one parent and fixation of ITS sequences from the other. However, to test this hypothesis one needs to compare well-resolved phylogenetic relationships generated from both chloroplast and nuclear data sets and sequence characteristics. Due to the low sequence divergence and less resolved relationship in the present study, we could not draw reliable conclusions in the speciation context. To better understand the phylogenetic relationship and speciation mechanism within *Solms-laubachia*, both additional independent gene phylogenies and the application of more sensitive molecular markers are needed, and both approaches are in progress.

SEED EPIDERMIS

Seed epidermis of 12 *Solms-laubachia* species and *Desideria baiogoinensis* was studied under SEM (Figs. 3–5). For each species, we checked three seeds from different individuals. Seeds are rugose in *S. platycarpa*, *S. lanata*, *S. retropilosa*, and *D. baiogoinensis* (Fig. 3A–H) and reticulate in the other species (Figs. 4, 5). Within these two seed types, there is a substantial variation in the sculpturing of the anticlinal cell walls and the fine ornamentation on

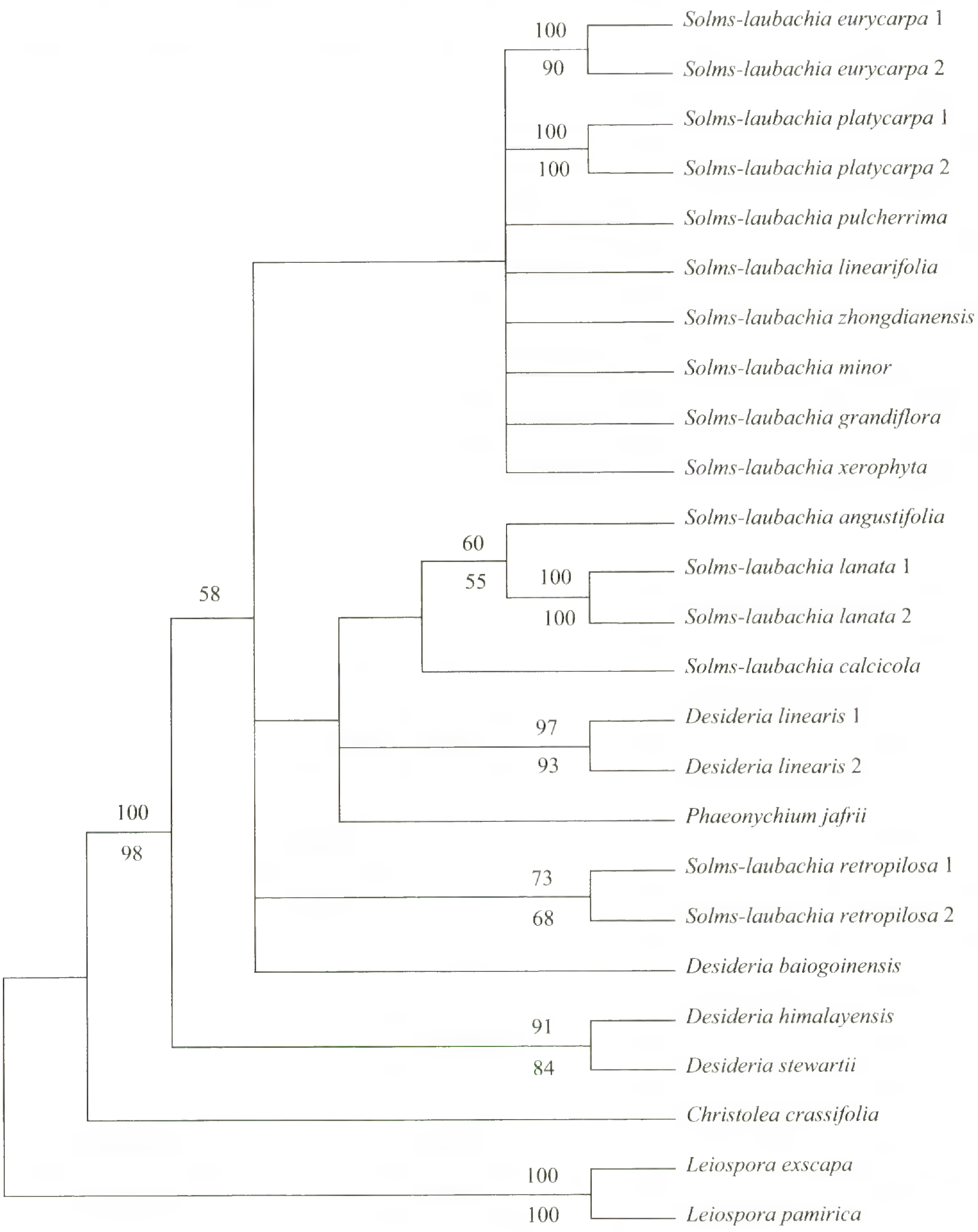
100
90
Solms-laubachia eurycarpa 1
Solms-laubachia eurycarpa 2
100
100
Solms-laubachia platycarpa 1
Solms-laubachia platycarpa 2
Solms-laubachia pulcherrima
Solms-laubachia linearifolia
Solms-laubachia zhongdianensis
Solms-laubachia minor
Solms-laubachia grandiflora
Solms-laubachia xerophyta
60
55
Solms-laubachia angustifolia
100
100
Solms-laubachia lanata 1
Solms-laubachia lanata 2
Solms-laubachia calcicola
58
97
93
Desideria linearis 1
Desideria linearis 2
Phaeonychium jafrii
100
98
73
68
Solms-laubachia retropilosa 1
Solms-laubachia retropilosa 2
Desideria baiogoinensis
91
84
Desideria himalayensis
Desideria stewartii
Christolea crassifolia
100
100
Leiospora exscapa
Leiospora pamirica

Figure 2. Strict consensus tree of 2565 MPTs based on *trnL-F* sequence. Numbers above and below branches are BS and jackknife percentages (values lower than 50% not shown).

the periclinal cell walls. The seed micro-sculpturing is useful in distinguishing different species with similar gross morphology. For example, *S. grandiflora* J. P. Yue, Al-Shehbaz & H. Sun and *S. linearifolia* are morphologically similar; however, the seed surface of *S. grandiflora* has the compound walls and smooth cells (Fig. 5C, D), distinguished from that of *S. linearifolia* with simple walls and minutely papillate cell surface (Fig. 5A, B). The seed epidermal micromorphology of *D. baiogoinensis* (Fig. 3G, H) was similar to that of *S. lanata* (Fig. 3C, D), with both showing striped periclinal cell walls. This common feature supports the merger of *Desideria* in *Solms-laubachia*. Such a conclusion is consistent with the

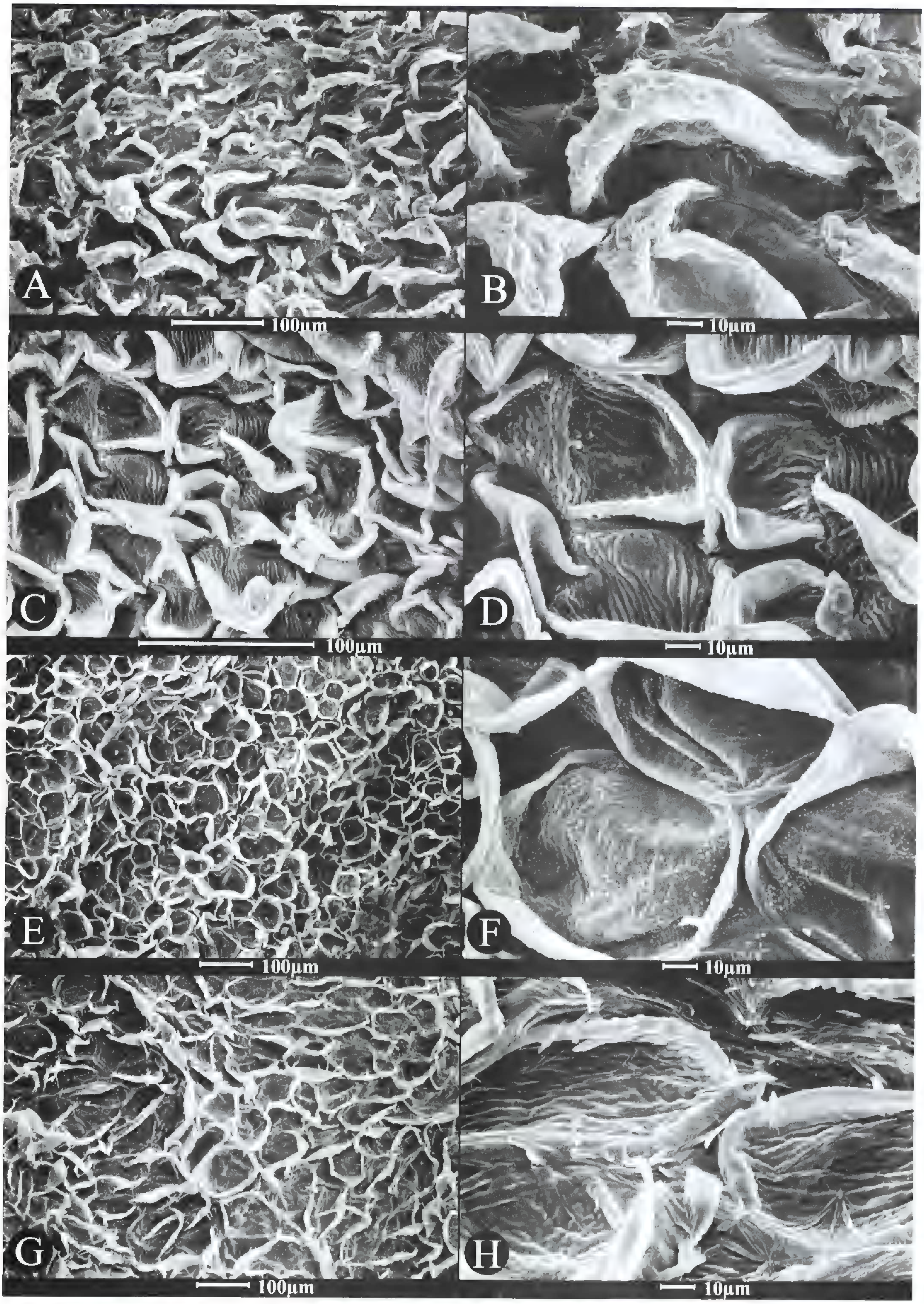

Figure 3. Seed epidermis of *Solms-laubachia* and *Desideria* under SEM. —A, B. *S. platycarpa* (×250; ×1000). —C, D. *S. lanata* (×250; ×1000). —E, F. *S. retropilosa* (×150; ×1000). —G, H. *D. baiogoinensis* (×150; ×1000). Voucher sources for the taxa are represented by asterisks in Table 1.

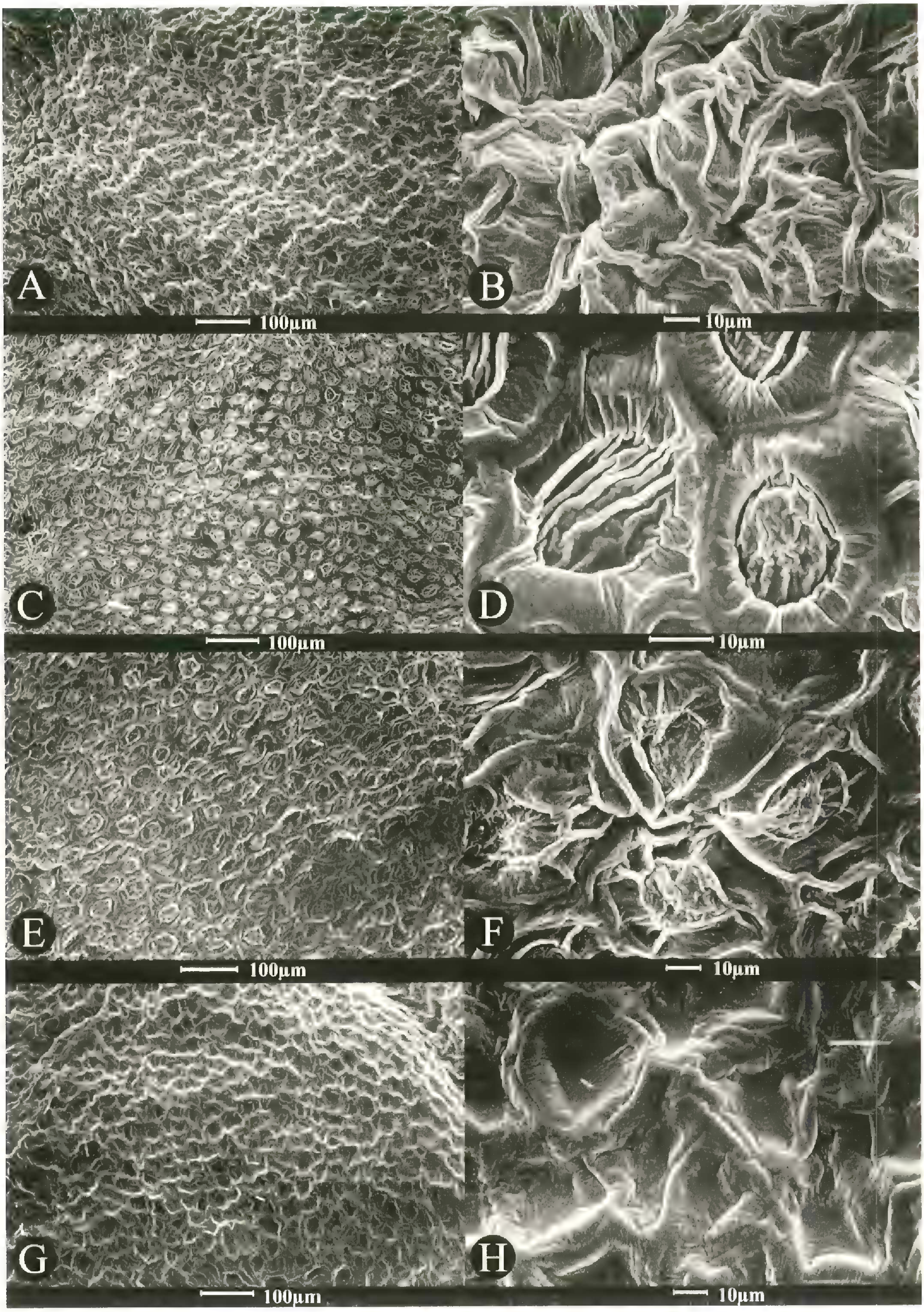

Figure 4. Seed epidermis of *Solms-laubachia* under SEM. A, B. *S. xerophyta* (×150; ×1000). —C, D. *S. angustifolia* (×150; ×1000). —E, F. *S. pulcherrima* (×150; ×1000). —G, H. *S. minor* (×150; ×1000). Voucher sources for the taxa are represented by asterisks in Table 1.

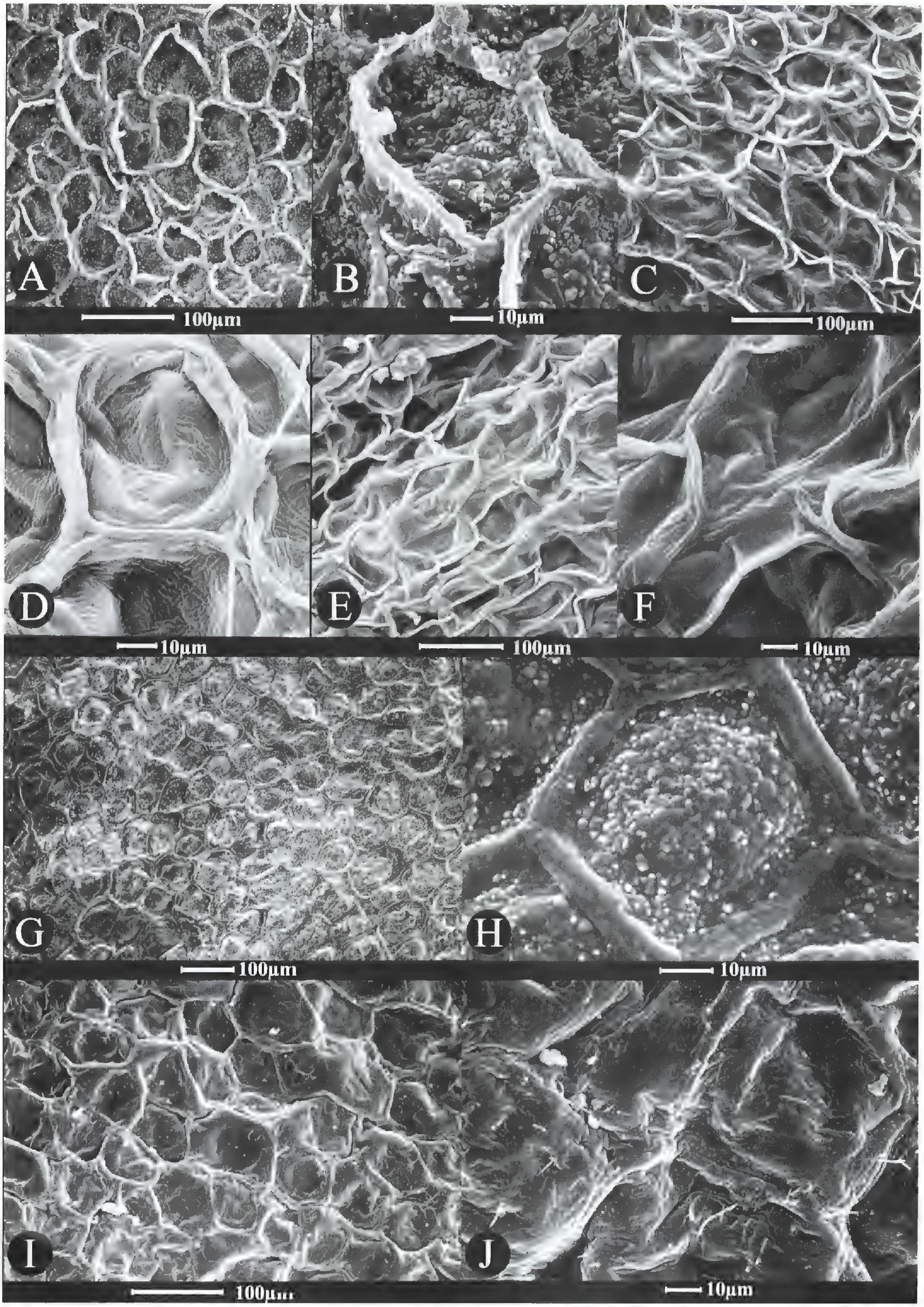

Figure 5. Seed epidermis of *Solms-laubachia* under SEM. —A, B. *S. linearifolia* (×250; ×1200). —C, D. *S. grandiflora* (×250; ×1000). —E, F. *S. calcicola* (×250; ×1000). —G, H. *S. eurycarpa* (×150; ×1500). —I, J. *S. zhongdianensis* (×250; ×1000). Voucher sources for the taxa are represented by asterisks in Table 1.

ITS and *trnL-F* data and previous findings of Yue et al. (2006).

TAXONOMIC CONSIDERATIONS

Solms-laubachia has been considered by Al-Shehbaz (2001) and Al-Shehbaz and Yang (2001) to be most closely related to *Desideria* (12 species; Al-Shehbaz, 2005) and *Leiospora* (six species; Botschantzev, 1955). All three genera are unique in the Brassicaceae by having fruits tardily dehiscent apically, rectangular in cross section, and readily detached at maturity from the pedicel. Furthermore, the fruit valves are adnate apically to the replum, are strongly angled at the margins, completely conceal the replum, and have prominent marginal veins. Al-Shehbaz et al. (2006) placed these three genera in the tribe Euclidieae, a disposition supported by the recent molecular findings of Warwick et al. (2007).

According to Al-Shehbaz (2001), *Solms-laubachia* differs from *Desideria* by having pinnately (vs. palmately) veined, entire (vs. apically 3- to 9 [to 11]-toothed) leaves and linear-oblong (vs. ovate to oblong) anthers. It differs from *Leiospora* by having wingless (vs. winged) seeds, equal (vs. unequal) sepals with the lateral pair non-saccate (vs. saccate), and entire or 2-lobed stigmas, but the lobes are neither decurrent nor connivent (vs. decurrent and connivent). However, molecular data (Yue et al., 2006; this study) strongly indicate that *Desideria* is polyphyletic and nested within *Solms-laubachia*, and *Solms-laubachia* and *Leiospora* are independent but closely related genera. Warwick et al. (2007) also found *Desideria* to be polyphyletic in relation to *Solms-laubachia*, but this study included only two species each of these two genera. Thus, the above-mentioned differences in leaf morphology between *Solms-laubachia* and *Desideria* are not consistent with the evolutionary relationships reflected by the molecular data. The four molecular markers used in this study and in Yue et al. (2006) show that *Phaeonychium jafrii* is embedded in the *Solms-laubachia–Desideria* clade to form one monophyletic group. Therefore, we transfer below *P. jafrii* and all *Desideria* sensu Al-Shehbaz (2001, 2005) to *Solms-laubachia* and recognize them as *S. jafrii* (Al-Shehbaz) J. P. Yue, Al-Shehbaz & H. Sun, *S. baiogoinensis* (K. C. Kuan & C. H. An) J. P. Yue, Al-Shehbaz & H. Sun, *S. flabellata* (Regel) J. P. Yue, Al-Shehbaz & H. Sun, *S. haranensis* (Al-Shehbaz) J. P. Yue, Al-Shehbaz & H. Sun, *S. himalayensis* (Cambess.) J. P. Yue, Al-Shehbaz & H. Sun, *S. incana* (Ovcz.) J. P. Yue, Al-Shehbaz & H. Sun, *S. linearis* (N. Busch) J. P. Yue, Al-Shehbaz & H. Sun, *S. mieheorum* (Al-Shehbaz) J. P. Yue, Al-Shehbaz & H. Sun, *S. mirabilis* (Pamp.) J. P. Yue, Al-Shehbaz & H. Sun, *S. nepalensis* (H. Hara) J. P. Yue, Al-Shehbaz & H. Sun, *S. prolifera* (Maxim.) J. P. Yue, Al-Shehbaz & H. Sun, and *S. stewartii* (T. Anderson) J. P. Yue, Al-Shehbaz & H. Sun. An expanded generic description of *Solms-laubachia* and a synopsis and key to all species are given below.

Solms-laubachia Muschl. in Diels, Notes Roy. Bot. Gard. Edinburgh 5: 205. 1912. Type: *Solms-laubachia pulcherrima* Muschl.

Desideria Pamp., Boll. Soc. Bot. Ital. 1926: 111. 1926. TYPE: *Desideria mirabilis* Pamp.

Ermaniopsis H. Hara, J. Jap. Bot. 49: 198. 1974. TYPE: *Ermaniopsis pumila* H. Hara.

Oreoblastus Suslova, Bot. Zhurn. (Moscow & Leningrad) 57: 648. 1972. TYPE: *Oreoblastus flabellatus* (Regel) Suslova.

Herbs perennial, sometimes pulvinate, with branched caudex covered with petioles of previous years; trichomes absent or simple, rarely short-stalked, 2-rayed; stems absent or present and simple, leafy or leafless. Basal leaves petiolate, rosulate, simple, entire or 3- to 9(to 11)-toothed, pinnately or palmately veined; cauline leaves absent or similar to basal ones and short petiolate to subsessile, not auriculate. Flowers solitary on long pedicels originating from center of rosette, or in (3 to)6- to 30-flowered, bracteate or ebracteate corymbose racemes elongating or not in fruit. Sepals oblong to ovate, free or united, persistent or deciduous, erect, equal, base of inner pair not saccate, margin membranous or not; petals purple, blue, pink, or rarely white, suborbicular, obovate, to spatulate, apex obtuse to emarginate; claw subequaling or longer than sepals; stamens 6; filaments free, dilated or not at base; anthers oblong-linear to ovate, not apiculate at apex; nectar glands 2 and lateral, or confluent and subtending bases of all filaments; median nectaries absent or present; ovules 6 to 30(to 70) per ovary. Fruit dehiscent silique or silicle, linear, oblong, ovate, or lanceolate, latiseptate, sessile, readily detached at maturity from pedicel, rectangular in cross section; valves papery, reticulate veined, with a prominent midvein and marginal veins, glabrous or pubescent, smooth, adnate with replum at fruit apex, margin angled; replum rounded, concealed by connate valve margins; septum complete or rarely perforated or reduced to a rim, membranous, translucent, rarely absent; style obsolete, rarely to 1 mm long; stigma capitate, entire or 2-lobed, lobes not decurrent. Seeds uniseriate or biseriate, wingless, broadly ovate to suborbicular or oblong, flattened; seed coat reticulate, rugose, or papillate, not mucilaginous when wetted; cotyledons accumbent.

Distribution and habitat. The 26 species of *Solms-laubachia* are distributed in Afghanistan, Bhutan, China (Gansu, Qinghai, Sichuan, Xinjiang, Xizang [Tibet], Yunnan), India (Himachal Pradesh, Kashmir, Punjab, Sikkim), Kyrgyzstan, Nepal, Pakistan, and Tajikistan. They are found at altitudes of (3200–)4000–6200 m and grow primarily on scree slopes and in rock crevices in the alpine areas of the Himalayan, Karakorum, Pamir, and Hengduan mountain ranges.

KEY TO THE SPECIES OF *SOLMS-LAUBACHIA*

1a. Flowers in racemes; stems mostly leafy.

2a. Leaves entire.

3a. Stems 1- or 2-leaved; leaf trichomes simple only; petals blue to purple, 10–17 mm long; fruit elliptic to broadly ovate, 8–17 mm wide . . . . 18. *S. platycarpa*

3b. Stems leafless; leaf trichomes a mixture of simple and branched; petals white to pink, 6.5–10 mm long; fruit linear, 1.5–2 mm wide . . . . 10. *S. jafrii*

2b. Leaves dentate.

4a. Sepals united, persistent until or after fruit dehiscence; septum reduced to a rim.

5a. Petals 11–13 × 5–6 mm; raceme 2- to 4-flowered, appearing solitary; Nepal . . . . 17. *S. nepalensis*

5b. Petals 5–8 × 1.5–3 mm; raceme with 5 or more flowers; China, Kashmir, Tajikistan . . . 16. *S. mirabilis*

4b. Sepals free, caducous or rarely persisting until about fruit maturity; septum complete or rarely perforated apically.

6a. Racemes bracteate throughout.

7a. Stem and pedicel trichomes forked . . . . 23. *S. stewartii*

7b. Stem and pedicel trichomes exclusively simple or absent.

8a. Fruit lanceolate to linear-lanceolate, (3–)4–6 mm wide; petals (6–)6.5–8 × 3–4 mm; seeds biseriate, (1.5–)1.8–2(–2.3) × 1–1.4 mm . . . . 8. *S. himalayensis*

8b. Fruit linear, (0.8–)1–1.7(–2) mm wide; petals 4–5(–5.5) × 1.5–2.5 mm; seeds uniseriate, 0.8–1.1 × 0.5–0.8 mm . . . . 13. *S. linearis*

6b. Racemes ebracteate.

9a. Filaments flattened, subapically toothed; petals 6.5–8 mm long . . . . 7. *S. haranensis*

9b. Filaments terete, toothless; petals 10–18 mm long.

10a. Plants canescent; leaf trichomes almost exclusively branched . . . . 9. *S. incana*

10b. Plants not canescent; leaf trichomes exclusively simple.

11a. Style 5–7 mm long; stigma entire; petals blue; ovules 10 to 16 per ovary . . . 14. *S. mieheorum*

11b. Style obsolete; stigma prominently 2-lobed; petals purple; ovules 14 to 24 per ovary . . . . 5. *S. flabellata*

1b. Flowers solitary from a basal rosette; scapes leafless.

12a. Leaves dentate.

13a. Fruit ovate to broadly lanceolate, 6–9 mm wide, prominently reticulate veined . . . . . 2. *S. baiogoinensis*

13b. Fruit linear to linear-lanceolate, 2–5 mm wide, obscurely veined.

14a. Leaf trichomes forked and simple; replum retrorsely ciliate; valves glabrous; sepals 3–4 mm long; petals 6–7 mm long . . . . 21. *S. pumila* (Kurz) F. Dvořák

14b. Leaf trichomes exclusively simple; replum spreading ciliate; valves pubescent; sepals 6–7 mm long; petals 11–14 mm long . . . . 19. *S. prolifera*

12b. Leaves entire.

15a. Leaves gray, densely lanate; seeds rugose.

16a. Leaf blade lanceolate- to oblanceolate-linear, rarely oblanceolate, retrorsely lanate, 1.5–5(–7) mm wide; fruit valves obscurely veined . . . . 22. *S. retropilosa*

16b. Leaf blade broadly spatulate, oblong, to obovate, spreading or antrorsely lanate, (5–)7–17 mm wide; fruit valves prominently veined . . . . 11. *S. lanata*

15b. Leaves green, glabrous or pilose; seeds reticulate.

17a. Sepals 2–3 mm long; fruits 2.8–3.2 mm wide . . . . 24. *S. sunhangiana*

17b. Sepals (4.5–)5–8(–11) mm long; fruits (4–)5–18 mm wide.

18a. Petioles of previous seasons papery; longest leaf blades rarely to 1 cm long . . . . 26. *S. zhongdianensis*

18b. Petioles of previous seasons remaining thickened; longest leaf blades (1.5–)2–4.5(–5.5) cm long.

19a. Leaf blade 0.3–1(–1.5) mm wide, grooved adaxially.

20a. Petioles not ciliate; leaf blades (2–)2.5–5.5(–7.7) cm long; fruits glabrous, narrowly oblong to linear . . . . 1. *S. angustifolia*

20b. Petioles ciliate; leaf blades 0.7–2(–2.5) cm long; fruits pubescent, lanceolate to linear-lanceolate . . . . 25. *S. xerophyta* (W. W. Sm.) H. F. Comber

19b. Leaf blade (1.5–)2–16(–23) mm wide, flattened adaxially.

21a. Leaf blade (7–)10–16(–23) mm wide; petiole strongly thickened, ± corky; sepals united . . . . 4. *S. eurycarpa* (Maxim.) Botsch.

21b. Leaf blade (1.5–)2–5(–7) mm wide; petiole slightly thickened; sepals free (sometimes united in *S. linearifolia*).

22a. Petioles of previous seasons papery . . . . 12. *S. linearifolia*

22b. Petioles of previous seasons thickened.
  23a. Petals pink.
    24a. Leaf blade to 1 cm long, glabrous, not ciliate . . . . 15. *S. minor* Hand.-Mazz.
    24b. Leaf blades (1.2–)1.8–4.5(–5.4) cm long, glabrous or sparsely pubescent, ciliate . . . . 6. *S. grandiflora*
  23b. Petals turquoise blue.
    25a. Seeds orbicular to broadly ovate; leaf trichomes crisped; caudex loosely branched; plants of scree slopes . . . . 20. *S. pulcherrima*
    25b. Seeds oblong; leaf trichomes if present then straight; caudex compactly branched; plants of rock crevices . . . . . . 3. *S. calcicola*

1. **Solms-laubachia angustifolia** J. P. Yue, Al-Shehbaz & H. Sun, sp. nov. TYPE: China. Sichuan: Yading Xian, Xianuoduoji, 28°23′N, 100°23′E, 4530 m, 10 Sep. 2002, *J. P. Yue 0250* (holotype, KUN!; isotype, MO!).

Herba perennis pulvinata, 2–6 cm alta. Folia basalia rosulata, linearia, (2–)2.5–5.5(–7.7) cm × 0.3–1(–1.3) mm, sparse pubescentia, integra; petiolis 0.4–1.5 cm longis, incrassatis; folia caulina nulla. Pedicelli fructiferi solitarii, 1–1.7 cm longi. Flores ignotes. Fructus lineares vel anguste oblongi, 1.6–4.2(–4.8) cm × (4–)4.5–8 mm, glabri. Semina late ovata vel suborbiculata, 2.1–3.4 × 1.2–2.8 mm.

Herbs perennial, pulvinate, 2–6 cm tall; caudex covered with petioles of previous years. Basal leaves rosulate; blade linear, (2–)2.5–5.5(–7.7) cm × 0.3–1(–1.3) mm, not ciliate, grooved adaxially, sparsely pubescent, base attenuate, margin entire; petioles 0.4–1.5 cm, thickened, not ciliate; cauline leaves absent. Fruiting pedicel solitary from basal rosette, 1–1.7 cm. Flowers not seen; ovules 14 to 22 per ovary. Fruit linear to narrowly oblong, 1.6–4.2(–4.8) cm × (4–)4.5–8 mm; valves glabrous, obscurely reticulate veined; septum complete; style (1–)1.2–1.6 mm; stigma entire to slightly 2-lobed. Seeds biseriate, broadly ovate to suborbicular, 2.1–3.4 × 1.2–2.8 mm. Chromosome number: $2n = 14$ (as *Solms-laubachia xerophyta* in Yue et al., 2004).

Distribution. Narrowly endemic to Sichuan Province, China.

IUCN Red List category. Critically Endangered (CR) (IUCN, 2001).

Discussion. Solms-laubachia angustifolia is closest morphologically to *S. xerophyta* and both have narrow leaves grooved adaxially and with thickened petioles. However, it differs by having non-ciliate petioles, leaf blades (2–)2.5–5.5(–7.7) cm long, and glabrous, narrowly oblong to linear fruits. By contrast, *S. xerophyta* has ciliate petioles, leaf blades 0.7–2(–2.5) cm long, and pubescent, lanceolate to linear-lanceolate fruits. Our previous study (Yue et al., 2006) revealed that *S. angustifolia* is sister to *S. minor*, whereas *S. xerophyta* falls in a separate branch of a polytomy that included the *S. minor–S. angustifolia* clade and the *S. pulcherrima–S. zhongdianensis* clade. Cytological studies (Yue et al., 2004) on *S. angustifolia* (as *S. xerophyta* therein) and *S. xerophyta* also found distinct differences in their chromosomal karyotypes. Furthermore, all previous records of *S. xerophyta* from Sichuan (e.g., Lan & Cheo, 1981; Tan et al., 1999; Al-Shehbaz & Yang, 2001) represent *S. angustifolia*, and therefore the two taxa occupy different provinces.

Paratypes. CHINA. **Sichuan:** Daocheng Xian, *J. F. C. Rock 16419* (GH), *J. F. C. Rock 16857* (MO, PE), *T. T. Yü 13043* (KUN, PE), *Qinghai-Xizang Team 5818* (PE).

2. **Solms-laubachia baiogoinensis** (K. C. Kuan & C. H. An) J. P. Yue, Al-Shehbaz & H. Sun, comb. nov. Basionym: *Christolea baiogoinensis* K. C. Kuan & C. H. An in C. Y. Wu, Fl. Xizangica 2: 388. 1985. *Desideria baiogoinensis* (K. C. Kuan & C. H. An) Al-Shehbaz, Ann. Missouri Bot. Gard. 87: 561. 2000. TYPE: China. Xizang: Baiogoin, 5100 m, 18 June 1976, *K. Y. Lang 9460* (holotype, PE!; isotype, PE!).

Distribution. China (Qinghai, Xizang) (see Al-Shehbaz, 2000).

3. **Solms-laubachia calcicola** J. P. Yue, Al-Shehbaz & H. Sun, sp. nov. TYPE: China. Xizang: Riwoqe Xian, Machala, 31°24′N, 96°40′E, 4770 m, 10 Aug. 2004, *D. E. Boufford, J. H. Chen, S. L. Kelley, J. Li, R. H. Ree, H. Sun, J. P. Yue & Y. H. Zhang 31975* (holotype, KUN!; isotypes, A!, MO!).

Herba perennis pulvinata, 2–5 cm alta. Folia basalia rosulata, linearia vel lanceolata, (1.8–)2.3–4.1(–4.4) cm × 1.9–2.5 mm, glabra vel sparse pubescentia, integra; petiolis (5.7–)6.5–8.9(–9.2) mm longis, incrassatis; folia caulina nulla. Pedicelli fructiferi solitarii, 3–3.5(–5) cm longi. Sepala libera, oblonga, 6.2–6.9 × 2.6–3.2 mm; petala turcosa, obovata, 1.5–1.8 × 0.6–1 cm; ovula 18 ad 28. Fructus anguste ovati vel lanceolati, 1.1–2.3(–2.5) cm × 5.1–8.9 (–9.2) mm, glabri vel sparse pubescentes. Semina oblonga, 2–2.5 × (1.2–)1.3–1.5(–1.7) mm.

Herbs perennial, pulvinate, 2–5 cm tall; caudex compactly branched, covered with petioles of previous years. Basal leaves rosulate; blade linear to lanceolate, (1.8–)2.3–4.1(–4.4) cm × 1.9–2.5 mm, glabrous or sparsely pubescent with straight trichomes, not ciliate, base attenuate, margin entire; petioles (5.7–)6.5–8.9(–9.2) mm, thickened; cauline leaves absent. Fruiting pedicels solitary from basal rosette, 3–3.5(–5) cm. Sepals free, oblong, 6.2–6.9 × 2.6–3.2 mm; petals turquoise blue, obovate, 1.5–1.8 × 0.6–1 cm; median filaments 3.8–4.5 mm; anthers 1–1.8 mm; ovules 18 to 28 per ovary. Fruit narrowly ovate to lanceolate, 1.1–2.3(–2.5) cm × 5.1–8.9(–9.2) mm, glabrous or sparsely pubescent; valves prominently reticulate veined; septum complete; style 0.5–1.5 mm; stigma slightly 2-lobed. Seeds oblong, uniseriate to biseriate, 2–2.5 × (1.2–)1.3–1.5(–1.7) mm.

Distribution. Narrowly endemic to Xizang Province, China.

IUCN Red List category. Critically Endangered (CR) (IUCN, 2001).

Discussion. *Solms-laubachia calcicola* resembles *S. pulcherrima* in being the only species of the genus with turquoise petals and in having thick petioles and similar flower size, but it differs by having oblong versus orbicular to broadly ovate seeds with coarser seed sculpture (Fig. 5E, F), as well as a thick and compactly branched (vs. slender and loosely branched) caudex. It grows in rock crevices instead of scree slopes, to which *S. pulcherrima* is restricted. Furthermore, molecular data (both ITS and *trnL-F*) clearly show that *S. calcicola* and *S. pulcherrima* fall into two separate clades in both analyses (Figs. 1, 2). The occurrence of turquoise petals in these two somewhat remotely related species would appear that this flower color evolved independently in them.

Paratype. CHINA. **Xizang:** Riwoqe Xian, Machala, 31°24′N, 96°40′E, 4770 m, *T. Y. Tu & J. W. Zhang 599* (KUN).

4. **Solms-laubachia eurycarpa** (Maxim.) Botsch., Bot. Mater. Gerb. Bot. Inst. Komarova Akad. Nauk S.S.S.R. 17: 169. 1955. Basionym: *Parrya eurycarpa* Maxim., Fl. Tangut. 1: 56. 1889. TYPE: China. Tibet: near Jagem-Gol, 20 July 1884, *N. M. Przewalski s.n.* (holotype, LE!; isotype, PE!).

Solms-laubachia pulcherrima Muschl. var. *latifolia* O. E. Schulz, Notizbl. Bot. Gart. Berlin-Dahlem 11: 229. 1931. Basionym: *Solms-laubachia latifolia* (O. E. Schulz) Y. Z. Lan & T. Y. Cheo, Acta Phytotax. Sin. 19: 477. 1981. TYPE: China. SW Sichuan: Mt. Konka, Risonquemba, Konkaling, 4475 m, June–Aug. 1928, *J. F. C. Rock 16870* (lectotype, designated by Al-Shehbaz & Yang, 2001: 375, B!; isotypes, E!, US!, W!).

Solms-laubachia dolicocarpa Y. Z. Lan & T. Y. Cheo, Acta Phytotax. Sin. 19: 477. 1981. TYPE: China. Sichuan: Zoige, 4300 m, 4 Aug. 1960, *Sichuan Drug Plant Expedition 20279* (holotype, NAS [as HJ]!).

Solms-laubachia eurycarpa var. *brevistipes* Y. Z. Lan & T. Y. Cheo, Acta Phytotax. Sin. 19: 476. 1981. TYPE: China. Qinghai: Nanggen, 4400 m, 9 July 1965, *Y. C. Yang 1121* (holotype, HNWP [as HQ]!; isotype, HNWP!).

Solms-laubachia eurycarpa var. *lasiophylla* R. F. Huang in S. W. Liu, Fl. Qinghaiica 1: 510. 1997. TYPE: China. Qinghai: Hen Xian, Waisxan Amishan, 19 July 1972, 4100–4200 m, *P. C. Kuo 9908* (holotype, HNWP [as NWBI]!).

Solms-laubachia gamosepala Al-Shehbaz & G. Yang, Harvard Pap. Bot. 5: 380. 2001. TYPE: China. Yunnan: Deqen, Beima Shan, N side of rd., limestone scree, 28°23′N, 99°01′E, 4700 m, 30 June 1994, *Alpine Garden Society Expedition to China ACE 855* (holotype, K!).

Distribution. China (Gansu, Qinghai, Sichuan, Xizang, Yunnan) (see Al-Shehbaz & Yang, 2001).

5. **Solms-laubachia flabellata** (Regel) J. P. Yue, Al-Shehbaz & H. Sun, comb. nov. Basionym: *Parrya flabellata* Regel, Bull. Soc. Imp. Naturalistes Moscou 43: 261. 1870. *Ermania flabellata* (Regel) O. E. Schulz, Bot. Jahrb. Syst. 66: 98. 1933. *Christolea flabellata* (Regel) N. Busch in Komarov, Fl. URSS 8: 330. 1939. *Oreoblastus flabellatus* (Regel) Suslova, Bot. Zhurn. (Moscow & Leningrad) 57: 651. 1972. *Desideria flabellata* (Regel) Al-Shehbaz, Ann. Missouri Bot. Gard. 87: 558. 2000. TYPE: [Kyrgyzstan]. southern Tian Shan, Dschaman-Daban, s.d., *Sewerzow s.n.* (holotype, LE!).

Christolea pinnatifida R. F. Huang, Acta Phytotax. Sin. 35: 556. 1997. TYPE: China. Qinghai: Maqen, Anyemaqen Mtn., 4800 m, 25 June 1981, *R. F. Huang CG-81-154* (holotype, HNWP!).

Distribution. Afghanistan, China (Qinghai, Xinjiang), Kyrgyzstan, Tajikistan (see Al-Shehbaz, 2000).

6. **Solms-laubachia grandiflora** J. P. Yue, Al-Shehbaz & H. Sun, sp. nov. TYPE: China. Sichuan: Xiancheng Xian, Rizhaosheng Shan, 29°6′N, 99°41′32″E, 4650 m, 15 July 2004, *D. E. Boufford, J. H. Chen, S. L. Kelley, J. Li, R. H. Ree, H. Sun, J. P. Yue & Y. H. Zhang 30727* (holotype, KUN!; isotypes, A!, MO!).

Herba perennis pulvinata, 3–7 cm alta. Folia basalia rosulata, linearia vel lineari-lanceolata, (1.2–)1.8–4.5(–5.4) cm × 1.5–2.3(–2.9) mm, glabra vel sparse pubescentia, integra; petiolis (5.2–)6.8–8.2(–10.2) mm longis, incrassatis; folia caulina nulla. Pedicelli fructiferi solitarii, 1.6–2.5(–3.2) cm longi. Sepala libera vel connata, oblonga, 6.1–7.7 × 2–2.9 mm; petala purpurea, obovata, 1.6–2.5 × (0.6–)0.8–0.9(–1.2) cm; ovula 14 ad 24. Fructus oblongi vel oblongo-lineares, 1–3.4(–4.8) cm × 4–11 mm, glabri vel sparse pubescentes. Semina late ovata vel suborbiculata, 2.4–3.6 × (1.6–)1.8–2.8(–3) mm.

Herbs perennial, pulvinate, 3–7 cm tall; caudex covered with petioles of previous years. Basal leaves rosulate; blade linear to linear-lanceolate, (1.2–)1.8–4.5(–5.4) cm × 1.5–2.3(–2.9) mm, glabrous or sparsely pubescent, ciliate, base attenuate, margin entire; petioles (5.2–)6.8–8.2(–10.2) mm, thickened; cauline leaves absent. Fruiting pedicels solitary from basal rosette, 1.6–2.5(–3.2) cm. Sepals free or united, oblong, 6.1–7.7 × 2–2.9 mm; petals purple, obovate, 1.6–2.5 × (0.6–)0.8–0.9(–1.2) cm; median filaments 4.5–5.6 mm; anthers 1.3–2 mm; ovules 14 to 24 per ovary. Fruit oblong to oblong-linear, 1–3.4(–4.8) cm × 4–11 mm, glabrous or sparsely pubescent; valves obscurely reticulate veined; septum complete; style 1.1–2.1 mm; stigma slightly 2-lobed. Seeds biseriate, broadly ovate to suborbicular, 2.4–3.6 × (1.6–)1.8–2.8(–3) mm.

Distribution. Narrowly endemic to Xiancheng Xian in Sichuan Province, China.

IUCN Red List category. Critically Endangered (CR) (IUCN, 2001).

Discussion. Solms-laubachia grandiflora most closely resembles *S. linearifolia*, especially in leaf morphology and flower color, but it differs by having thickened instead of thinner, papery petioles, narrower leaves (1.5–2.3[–2.9] vs. 1.7–4.1[–5] mm wide), smaller seeds (2.4–3.6 × [1.6–]1.8–2.8[–3] mm vs. 3.5–4 × 2.5–3.5 mm), and shorter (1–3.4[–4.8] cm vs. [3–]4.5–6.5[–8] cm), less pubescent fruits. Furthermore, they differ in seed morphology, and *S. grandiflora* (Fig. 5C, D) has compound walls and smooth cells, whereas *S. linearifolia* (Fig. 5A, B) has simple walls and a minutely papillate cell surface. The molecular data from ITS (Fig. 1) show that *S. grandiflora* is clustered with *S. calcicola* and *S. sunhangania*, whereas *S. linearifolia* falls in a separate, more basal clade.

Paratype. CHINA. **Sichuan:** Xiancheng Xian, Rizhaosheng Shan, 29°6′N, 99°41′32″E, 4650 m, 18 Oct. 2005, *J. P. Yue 5120* (KUN, MO).

7. **Solms-laubachia haranensis** (Al-Shehbaz) J. P. Yue, Al-Shehbaz & H. Sun, comb. nov. Basionym: *Desideria haranensis* Al-Shehbaz, Ann. Missouri Bot. Gard. 87: 559. 2000, replacement name for *Ermaniopsis pumila* H. Hara, J. Jap. Bot. 49: 200. 1974, non *Solms-laubachia pumila* (Kurz) F. Dvořák, Folia Prirodoved. Fak. Univ. Purkyne Brne, Biol. 13(4): 24. 1972. TYPE: Nepal. ca. 5 mi. SW of Saldanggaon, very loose scree, 19,500 ft. [5944 m], 26 June 1952, *N. Polunin, W. R. Sykes & L. H. J. Williams 24* (holotype, BM!; isotypes, A!, BM!, E!).

Distribution. Nepal.

8. **Solms-laubachia himalayensis** (Cambess.) J. P. Yue, Al-Shehbaz & H. Sun, comb. nov. Basionym: *Cheiranthus himalayensis* Cambess. in Jacquem., Voy. Inde 4: 14. 1844. *Ermania himalayensis* (Cambess.) O. E. Schulz, Notizbl. Bot. Gart. Berlin-Dahlem 9: 1080. 1927. *Oreoblastus himalayensis* (Cambess.) Suslova, Bot. Zhurn. (Moscow & Leningrad) 57: 652. 1972. *Desideria himalayensis* (Cambess.) Al-Shehbaz, Ann. Missouri Bot. Gard. 87: 555. 2000. TYPE: [W Xizang], "in declivitate orientali jugi vulgò Kioubrung-ghauti in Tartariâ sinensi," *V. Jacquemont 1782* (holotype, P!; isotypes, K!, P!).

Distribution. China (Qinghai, Xizang), India (Himachal Pradesh, Kashmir, Punjab), Nepal (see Al-Shehbaz, 2001).

9. **Solms-laubachia incana** (Ovcz.) J. P. Yue, Al-Shehbaz & H. Sun, comb. nov. Basionym: *Christolea incana* Ovcz., Sovetsk. Bot. 1941(1 & 2): 151. 1941. *Ermania incana* (Ovcz.) Botsch., Bot. Mater. Gerb. Bot. Inst. Komarova Akad. Nauk S.S.S.R. 17: 164. 1955. *Oreoblastus incanus* (Ovcz.) Suslova, Bot. Zhurn. (Moscow & Leningrad) 57: 652. 1972. *Desideria incana* (Ovcz.) Al-Shehbaz, Ann. Missouri Bot. Gard. 87: 558. 2000. TYPE: Tajikistan. Darvaz: Mt. Masar, glacier Abdul Gassan, 11,000–12,000 ft. [3353–3658 m], 23 July 1899, *V. I. Lipsky 1936* (holotype, LE!).

Distribution. Tajikistan.

10. **Solms-laubachia jafrii** (Al-Shehbaz) J. P. Yue, Al-Shehbaz & H. Sun, comb. nov. Basionym: *Phaeonychium jafrii* Al-Shehbaz, Nordic J. Bot. 20: 160. 2000. TYPE: China. Xizang [Tibet]: hills E of Lhasa, 14,000 ft. [4267 m], on rock faces, 14 June 1942, *F. Ludlow & G. Sherriff 8714* (holotype, BM!).

Distribution. Bhutan, China (Xizang), Nepal (see Al-Shehbaz, 2000).

11. **Solms-laubachia lanata** Botsch., Bot. Mater. Gerb. Bot. Inst. Komarova Akad. Nauk S.S.S.R. 17: 171. 1955. TYPE: China. Tibet [Xizang]: near Yerpa Monastery, 14,000 ft. [4267 m], Aug. 1821, *R. S. Kennedy 9* (holotype, K!).

Distribution. China (Xizang).

12. **Solms-laubachia linearifolia** (W. W. Sm.) O. E. Schulz, Notizbl. Bot. Gart. Berlin-Dahlem 9: 477. 1926. Basionym: *Parrya linearifolia* W. W. Sm., Notes Roy. Bot. Gard. Edinburgh 11: 219.

1919, non *P. linearifolia* Pavlov, Vestn. Akad. Nauk Kazakhsk. S.S.R. 1: 29. 1949. TYPE: China. Yunnan: Beima Shan, Mekong–Yangtze divide, 28°20′N, 14,500 ft. [4420 m], Aug. 1914, *G. Forrest 13,235* (lectotype, designated here, E!; isotype, E!).

Solms-laubachia linearifolia var. *leiocarpa* O. E. Schulz, Notizbl. Bot. Gart. Berlin-Dahlem 9: 477. 1926. TYPE: China. NW Yunnan: Mt. Peimashan, Mekong–Yangtze divide betw. Atuntze & Pungtzera, June 1923, *J. F. C. Rock 9304* (holotype, B!; isotypes, E!, GH!, US!).

Distribution. China (Sichuan, Xizang, Yunnan) (see Al-Shehbaz & Yang, 2001).

13. Solms-laubachia linearis (N. Busch) J. P. Yue, Al-Shehbaz & H. Sun, comb. nov. Basionym: *Christolea linearis* N. Busch in Komarov, Fl. URSS 8: 636. 1939. *Ermania linearis* (N. Busch) Botsch., Bot. Mater. Gerb. Bot. Inst. Komarova Akad. Nauk S.S.S.R. 17: 166. 1955. *Oreoblastus linearis* (N. Busch) Suslova, Bot. Zhurn. (Moscow & Leningrad) 57: 652. 1972. *Desideria linearis* (N. Busch) Al-Shehbaz, Ann. Missouri Bot. Gard. 87: 556. 2000. TYPE: Tajikistan. Pamir: Schugnan, Abchary, 2 Aug. 1904, *B. Fedtschenko s.n.* (holotype, LE!).

Ermania parkeri O. E. Schulz, Repert. Sp. Nov. Regni Veg. 31: 333. 1933. *Christolea parkeri* (O. E. Schulz) Jafri, Notes Roy. Bot. Gard. Edinburgh 22: 52. 1955. *Oreoblastus parkeri* (O. E. Schulz) Suslova, Bot. Zhurn. (Moscow & Leningrad) 57: 653. 1972. TYPE: [India.] Kashmir: Sonamarg, Luderwas, 13,000 ft. [3962 m], 11 Aug. 1928, *R. R. Stewart 9874A* (holotype, B!).

Ermania kashmiriana Dar & Naqshi, J. Bombay Nat. Hist. Soc. 87: 274. 1990. TYPE: [India.] Kashmir: Shalimar, Sonamarg (Sind Valley), 3900 m, 20 Aug. 1983, *G. H. Dar 7786* (holotype, KASH not seen).

Ermania kachrooi Dar & Naqshi, J. Bombay Nat. Hist. Soc. 87: 277. 1990. TYPE: [India.] Kashmir: Baltal, Sonamarg (Sind Valley), 3200 m, 2 Sep. 1982, *G. H. Dar 3934* (holotype, KASH not seen; isotypes, KASH not seen, MO!).

Distribution. China (Xinjiang, Xizang), India (Kashmir), Nepal, Tajikistan (see Al-Shehbaz & Yang, 2001).

14. Solms-laubachia mieheorum (Al-Shehbaz) J. P. Yue, Al-Shehbaz & H. Sun, comb. nov. Basionym: *Desideria mieheorum* Al-Shehbaz, Novon 15: 1. 2005. TYPE: China. Tibet [Xizang]: Chang La, N of Sangsang, 29°41′N, 86°43′E, pioneer on frost debris, 5480–5600 m, 15 Sep. 2003, *G. & S. Miehe 03-112-21* (holotype, MO!).

Distribution. China (Xizang).

15. Solms-laubachia minor Hand.-Mazz., Anz. Akad. Wiss. Wien, Math.-Naturwiss. Kl. 59: 246. 1922. TYPE: China. Sichuan: Mt. Holoscha, 27°48′N, betw. Yenyuen & Kwapi, 4325 m, 18 May 1914, *H. F. Handel-Mazzetti 2318* (holotype, WU!; isotypes, E!, P!, W!).

Distribution. China (Sichuan).

16. Solms-laubachia mirabilis (Pamp.) J. P. Yue, Al-Shehbaz & H. Sun, comb. nov. Basionym: *Desideria mirabilis* Pamp., Boll. Soc. Bot. Ital. 1926: 111. 1926. *Christolea mirabilis* (Pamp.) Jafri, Fl. W. Pakistan 55: 160. 1973. TYPE: [Pakistan. Kashmir:] Karakorum, above Caracash Valley, Chisil Gilgha Pass, 5360 m, 28 June 1914, *G. Dainelli & O. Marinelli 2* (lectotype, designated here, FI not seen, FI photo at HB!).

Christolea scaposa Jafri, Notes Roy. Bot. Gard. Edinburgh 22: 58. 1955. TYPE: [Pakistan.] Kashmir: Shaksgam Valley, 4950 m, 3 July 1926, *R. C. Clifford 7* (holotype, K!).

Christolea karakorumensis Y. H. Wu & C. H. An, Acta Phytotax. Sin. 32: 577. 1994. TYPE: China. Xinjiang: Pishan [Guma], Shenxianwan, 5250 m, 25 July 1989, *Karakorum-Kunlun Expedition 5100* (holotype, HNWP [as NWBI]!).

Desideria pamirica Suslova, Novosti Sist. Vyssh. Rast. 10: 163. 1973. *Christolea suslovaeana* Jafri, Fl. West Pakistan 55: 158. 1973, replacement names for *D. pamirica* non *Christolea pamirica* Korshinsky, Mém. Acad. Imp. Sci. Saint Pétersbourg, ser. 8, 4: 89. 1896. TYPE: Tajikistan. Pamir: above Czeczekty, near Zor, 4900 m, 10 Aug. 1970, *T. Suslova s.n.* (holotype, LE!).

Distribution. China (Xinjiang), Pakistan (Kashmir), Tajikistan (see Al-Shehbaz, 2001).

17. Solms-laubachia nepalensis (H. Hara) J. P. Yue, Al-Shehbaz & H. Sun, comb. nov. Basionym: *Desideria nepalensis* H. Hara, J. Jap. Bot. 50: 264. 1975. TYPE: Nepal. Barum Valley, 17,700 ft. [5394 m], 26 May 1954, *L. W. Swan 71-72* (holotype, BM!).

Distribution. Nepal.

18. Solms-laubachia platycarpa (Hook. f. & Thomson) Botsch., Bot. Mater. Gerb. Bot. Inst. Komarova Akad. Nauk S.S.S.R. 17: 171. 1955. Basionym: *Parrya platycarpa* Hook. f. & Thomson, J. Proc. Linn. Soc., Bot. 5: 136. 1861, non *P. platycarpa* Rydb., Bull. Torrey Bot. Club 39: 326. 1912. TYPE: [India.] Sikkim: alpine region, 17,000 ft. [5182 m], s.d., *J. D. Hooker s.n.* (holotype, K!).

Parrya finchiana Dunn, Bull. Misc. Inform. Kew 1927: 247. 1927. TYPE: Tibet [Xizang]: along Chongphu torrent, ca. 20 mi. NE of Mt. Everest, 17,000 ft. [5182 m], 8 June 1922, *E. F. Norton 41* (holotype, K!).

Solms-laubachia orbiculata Y. Z. Lan & T. Y. Cheo, Acta Phytotax. Sin. 19: 473. 1981. TYPE: China. Xizang: Cona, 5020 m, 20 July 1975, *C. Y. Wu & S. K. Chen 75-1129* (holotype, HNWP [as HQ]!; isotype, KUN!).

Distribution. Bhutan, China (Xizang), India (Sikkim).

19. Solms-laubachia prolifera (Maxim.) J. P. Yue, Al-Shehbaz & H. Sun, comb. nov. Basionym: *Parrya prolifera* Maxim., Fl. Tangut. 56. 1889. *Ermania prolifera* (Maxim.) O. E. Schulz, Bot. Jahrb. Syst. 66: 98. 1933. *Christolea prolifera* (Maxim.) Ovcz., Sovetsk. Bot. 1941(1 & 2): 151. 1941. *C. prolifera* (Maxim.) Jafri, Notes Roy. Bot. Gard. Edinburgh 22: 53. 1955. *Desideria prolifera* (Maxim.) Al-Shehbaz, Ann. Missouri Bot. Gard. 87. 559. 2000. TYPE: China. Tibet [Xizang]: Kon-chun-ua, 14,500 ft., 3 July 1884, *N. M. Przewalski s.n.* (holotype, LE!; isotypes, K!, P!, PE!).

Distribution. China (Qinghai, Xizang) (see Al-Shehbaz, 2000).

20. Solms-laubachia pulcherrima Muschl. in Diels, Notes Roy. Bot. Gard. Edinburgh 5: 206. 1912. TYPE: China. NW Yunnan: E flank of Lichiang Range, 27°20′N, 12,000 ft. [3658 m], May 1906, *G. Forrest 2164* (holotype, B!; isotypes, BM!, E!, P!).

Pegaeophyton sinense (Hemsl.) Hayek & Hand.-Mazz. var. *stenophyllum* O. E. Schulz, Notizbl. Bot. Gart. Berlin-Dahlem 9: 477. 1926. TYPE: China. Yunnan: Yangtze watershed, Prefect. Distr. of Likiang, E slope of Likiang snow range, 5300 m, 11 Aug. 1922, *J. F. C. Rock 5719* (holotype, B!; isotypes, E!, GH!, P!, US!).

Solms-laubachia pulcherrima f. *angustifolia* O. E. Schulz, Notizbl. Bot. Gart. Berlin-Dahlem 9: 477. 1926. TYPE: China. Yunnan: Yangtze watershed, W slopes of Likiang snow range, 13,000 ft. [3962 m], 30 May–6 June 1922, *J. F. C. Rock 4277* (holotype, B!; isotypes, E!, GH!, P!, US!, W!).

Solms-laubachia pulcherrima f. *atrichophylla* Hand.-Mazz., Anz. Akad. Wiss. Wien, Math.-Naturwiss. Kl. 62: 24. 1926. TYPE: China. Sichuan: Mt. Gonschiga, Muli monastery, Yungning toward Dschungdien, 4500 m, *H. F. Handel-Mazzetti 7503* (holotype, WU!; isotype, W!).

Parrya ciliaris Bureau & Franch., J. Bot. (Morot) 5: 20. 1891. *Solms-laubachia ciliaris* (Bureau & Franch.) Botsch., Bot. Mater. Gerb. Bot. Inst. Komarova Akad. Nauk S.S.S.R. 17: 169. 1955. TYPE: China. Tibet [Xizang]: rte. de Batang, 12 May 1890, *M. Bonvalot & H. d'Orléans s.n.* (holotype, P!).

Distribution. China (Sichuan, Xizang, Yunnan).

21. Solms-laubachia pumila (Kurz) F. Dvořák, Folia Prirodoved. Fak. Univ. Purkyne Brne, Biol. 13(4): 24. 1972. Basionym: *Parrya pumila* Kurz, Flora 55: 285. 1872. *Vvedenskyella pumila* (Kurz) Botsch., Bot. Mater. Gerb. Bot. Inst. Komarova Akad. Nauk S.S.S.R. 17: 176. 1955. *Christolea pumila* (Kurz) Jafri, Fl. W. Pakistan 55: 157. 1973. *Desideria pumila* (Kurz) Al-Shehbaz, Ann. Missouri Bot. Gard. 87: 560. 2000. TYPE: [Kashmir.] Rupschu, 15,000–18,000 ft. [4572–5486 m], s.d., *F. Stoliczka s.n.* (holotype, CAL not seen; isotype, K!).

Ermania koelzii O. E. Schulz, Repert. Spec. Nov. Regni Veg. 31: 332. 1933. TYPE: [Pakistan] Kashmir. Rupshu, Kyensa La, 19,000 ft. [5791 m], 9 July 1931, *W. Koelz 2231* (holotype, B!).

Ermania bifaria Botsch., Bot. Mater. Gerb. Bot. Inst. Komarova Akad Nauk S.S.S.R. 17: 164. 1955. *Oreoblastus bifarius* (Botsch.) Suslova, Bot. Zhurn. (Moscow & Leningrad) 57: 652. 1972. TYPE: China. Xinjiang: Kuen-Lun, Humboldt Range, Ulan-Bulak, 4200 m, 30 June 1894, *W. Roborowski s.n.* (holotype, LE!).

Distribution. China (Xinjiang, Xizang), Pakistan (Kashmir).

22. Solms-laubachia retropilosa Botsch., Bot. Mater. Gerb. Bot. Inst. Komarova Akad. Nauk S.S.S.R. 17: 171. 1955. TYPE: China. [Xizang] Tibet (as Sikkan): betw. Toutan & Lamaja, Alabosan (Ngarolak), 27 May 1893, *V. Kaschkarov s.n.* (holotype, LE!; isotype, PE!).

Solms-laubachia floribunda Y. Z. Lan & T. Y. Cheo, Acta Phytotax. Sin. 19: 475. 1981. TYPE: China. Xizang: Zogang, 5100 m, 3 July 1976, *Qinghai-Xizang Expedition 12173* (holotype, PE [as HC]!; isotypes, HNWP!, KUN!, NAS!).

Distribution. China (Sichuan, Xizang, Yunnan) (see Al-Shehbaz & Yang, 2001).

23. Solms-laubachia stewartii (T. Anderson) J. P. Yue, Al-Shehbaz & H. Sun, comb. nov. Basionym: *Cheiranthus stewartii* T. Anderson in J. D. Hooker, Fl. Brit. India 1: 132. 1872. *Ermania stewartii* (T. Anderson) O. E. Schulz, Bot. Jahrb. Syst. 66: 98. 1933. *Christolea stewartii* (T. Anderson) Jafri, Notes Roy. Bot. Gard. Edinburgh 22: 53. 1955. *Oreoblastus stewartii* (T. Anderson) Suslova, Bot. Zhurn. (Moscow & Leningrad) 57: 653. 1972. *Desideria stewartii* (T. Anderson) Al-Shehbaz, Ann. Missouri Bot. Gard. 87: 556. 2000. TYPE: [India] Kashmir. Ladak, 15,000–16,500 ft. [4572–5029 m], s.d., *J. L. Stewart s.n.* (holotype, K!; isotype, E!).

Distribution. China (Xizang), India (Himachal Pradesh, Punjab, Kashmir) (see Al-Shehbaz & Yang, 2001).

24. Solms-laubachia sunhangiana J. P. Yue & Al-Shehbaz, sp. nov. TYPE: China. Sichuan: Jiulong Xian, Tanggu Xiang, NW of city of Jiulong, Wuxu

Hai (Wuxu Lake), 29°9′11″N, 101°24′25″E, *Abies*, *Picea*, *Quercus* forest with *Rhododendron* understory & open, grazed, dry, and boggy meadows, crevices of rocks, 4175 m, 22 June 2005, *D. E. Boufford, J. H. Chen, S. L. Kelley, J. Li, R. H. Ree, H. Sun, J. P. Yue & Y. H. Zhang 33464* (holotype, KUN!; isotypes, A!, MO!).

Herba perennis pulvinata, 1–3 cm alta. Folia basalia rosulata, linearia vel lineari-oblanceolata, 0.8–2.5 cm × 1–2.5 mm, sparse pubescentia, integra; petiolis 3.5–5.5 mm longis, incrassatis; folia caulina nulla. Pedicelli fructiferi solitarii, 0.8–1.2 cm longi. Sepala libera, oblonga, 2–3 × 1–1.2 mm, sparse pilosa; petala ca. 6 mm longa; ovula 8 ad 12. Fructus lineares vel lineari-lanceolati, 1.6–2.5 cm × 2.8–3.2 mm, pubescentes. Semina ovato-oblonga, ca. 2.5 × 1.5 mm.

Herbs perennial, pulvinate, 1–3 cm tall; caudex covered with petioles and intact leaves of previous years. Basal leaves rosulate; blade linear to linear-oblanceolate, 0.8–2.5 cm × 1–2.5 mm, grooved proximally, sparsely pubescent, not ciliate, base attenuate, margin entire; petioles 3.5–5.5 mm, thickened; cauline leaves absent. Fruiting pedicels solitary from basal rosette, 0.8–1.2 cm long. Sepals free, oblong, 2–3 × 1–1.2 mm, sparsely pilose; petals ca. 6 mm; anthers ca. 1 mm; ovules 8 to 12 per ovary. Fruit linear-lanceolate to linear, 1.6–2.5 cm × 2.8–3.2 mm; valves pubescent, obscurely reticulate veined; septum complete; style 0.6–1 mm; stigma strongly 2-lobed. Seeds ovate-oblong, ca. 2.5 × 1.5 mm.

Distribution. Narrowly endemic to Jiulong Xian in Sichuan Province, China.

IUCN Red List category. Critically Endangered (CR) (IUCN, 2001).

Discussion. Solms-laubachia sunhangiana is named in honor of Sun Hang, deputy director of the Kunming Institute of Botany, for his continuous support of fieldwork on the genus. This novelty is easily distinguished from the remaining species of the genus with entire leaves by having much smaller flowers (sepals 2–3 mm vs. [5.5–]5–8[–11] mm long) and narrower fruits (2–3 mm vs. [4–]5–18 mm wide). It is closely related to *S. xerophyta*, which it resembles by having persistent, linear, narrow (less than 3 mm wide) leaves grooved proximally. Such leaves are also found in *S. zhongdianensis*, a species unique in the genus by its thinner, papery petioles instead of thickened ones.

25. Solms-laubachia xerophyta (W. W. Sm.) H. F. Comber, Notes Roy. Bot. Gard. Edinburgh 18: 249. 1934. Basionym: *Parrya xerophyta* W. W. Sm., Notes Roy. Bot. Gard. Edinburgh 12: 217. 1920. TYPE: China. Yunnan: NE of Chungtien, 27°55′N, July 1918, *G. Forrest 16444* (holotype, E!; isotypes, E!, K!, P!, W!).

Distribution. China (Sichuan, Yunnan) (see Al-Shehbaz & Yang, 2001).

26. Solms-laubachia zhongdianensis J. P. Yue, Al-Shehbaz & H. Sun, Ann. Bot. Fenn. 42: 156. 2005. TYPE: China. Yunnan: Shangri-la Co., Mt. Shika, scree, sandy areas, 27°47′N, 99°35′E, ca. 4450 m, 27 Sep. 2001, *J. P. Yue 154* (holotype, KUN!; isotype, MO!).

Distribution. China (Yunnan).

CONSERVATION STATUS

The four new species described above (*S. angustifolia*, *S. calcicola*, *S. grandiflora*, and *S. sunhangiana*) are known from only their type specimens or a few additional collections. Following the IUCN guidelines (IUCN, 2001), and because all four have very narrow distribution ranges, our preliminary conservation assessment would indicate that they are Critically Endangered (CR).

Literature Cited

Al-Shehbaz, I. A. 1984. The tribes of Cruciferae (Brassicaceae) in the southeastern United States. J. Arnold Arbor. 65: 343–373.

———. 1988. The genera of Anchonieae (Hesperideae) (Cruciferae; Brassicaceae) in the southeastern United States. J. Arnold Arbor. 69: 193–212.

———. 2000. A review of gamosepaly in the Brassicaceae and a revision of *Desideria*, with a critical evaluation of related genera. Ann. Missouri Bot. Gard. 87: 549–563.

———. 2005. *Desideria mieheorum* (Brassicaceae), a new species from Tibet. Novon 15: 1–3.

——— & G. Yang. 2001. A revision of *Solms-laubachia* (Brassicaceae). Harvard Pap. Bot. 5(2): 371–381.

———, M. A. Beilstein & E. A. Kellogg. 2006. Systematics and phylogeny of the Brassicaceae (Cruciferae): An overview. Pl. Syst. Evol. 259: 89–120.

An, Z. X. [An C. H]. 1995. Cruciferae. Pp. 38–229 *in* Z. M. Mao (editor), Flora Xinjiangensis, Vol. 2(2). Xinjiang Science, Technology, and Hygiene Publishing House, Urumqi.

Baum, D. A., R. L. Small & J. F. Wendel. 1998. Biogeography and floral evolution of baobabs (*Adansonia*, Bombacaceae) as inferred from multiple data sets. Syst. Biol. 47: 181–207.

Beilstein, M. A., I. A. Al-Shehbaz & E. A. Kellogg. 2006. Brassicaceae phylogeny and trichome evolution. Amer. J. Bot. 93: 607–619.

Botschantzev, V. 1955. De Cruciferis notae criticae. Bot. Mater. Gerb. Bot. Inst. Komarova Akad. Nauk S.S.S.R. 17: 160–178.

Cunningham, C. W. 1997. Can three incongruence tests predict when data should be combined? Molec. Biol. Evol. 14: 733–740.

Farris, J. S., A. G. Kluge & M. J. Eckardt. 1970. A numerical approach to phylogenetic systematics. Syst. Zool. 19: 172–191.

———, M. Källersjö, A. G. Kluge & C. Buil. 1994. Testing significance of incongruence. Cladistics 10: 315–319.

———, ———, ——— & ———. 1995. Constructing a significance test for incongruence. Syst. Biol. 44: 570–572.

Fitch, W. M. 1971. Toward defining the course of evolution: Minimal change for a specific tree topology. Syst. Zool. 20: 406–416.

Hedge, I. C. 1976. A systematic and geographical survey of the Old World Cruciferae. Pp. 1–45 *in* J. G. Vaughan, A. J. MacLeod & B. M. G. Jones (editors), The Biology and Chemistry of Cruciferae. Academic Press, London.

Huang, R. F. 1997. Cruciferae. Pp. 410–505 *in* S. W. Liu (editor), Flora Qinghaiica, Vol. 1. Qinghai People's Publishing House, Xining.

IUCN. 2001. IUCN Red List Categories and Criteria Version 3.1. Prepared by the IUCN Species Survival Commission. IUCN, Gland, Switzerland, and Cambridge, United Kingdom.

Janchen, E. 1942. Das system der Cruciferae. Oesterr. Bot. Z. 91: 1–28.

Koch, M., I. A. Al-Shehbaz & K. Mummenhoff. 2003. Molecular systematics, evolution, and population biology in the mustard family (Brassicaceae). Ann. Missouri Bot. Gard. 90: 151–171.

Kuan, K. C. 1985. *Solms-laubachia*. Pp. 381–384 *in* C. Y. Wu (editor), Flora Xizangica, Vol. 2. Science Press, Beijing.

Lan, Y. Z. 1987. *Solms-laubachia*. Pp. 326–339 *in* T. Y. Cheo (editor), Flora Reipublicae Popularis Sinicae, Vol. 33. Science Press, Beijing.

——— & T. Y. Cheo. 1981. On the Chinese genus *Solms-laubachia* Muschler (Cruciferae). Acta Phytotax. Sin. 19: 472–480.

Li, X. W. 1995. *Solms-laubachia*. Pp. 96–100 *in* C. Y. Wu, C. Chen & S. K. Chen (editors), Flora Yunnanica, Vol. 6. Science Press, Beijing.

Mitchell-Olds, T., I. A. Al-Shehbaz, M. Koch & T. F. Sharbel. 2005. Crucifer evolution in the post-genomic era. Pp. 119–137 *in* R. J. Henry (editor), Plant Diversity and Evolution: Genotypic and Phenotypic Variation in Higher Plants. CABI Publishing, Oxfordshire and Cambridge, United Kingdom.

Murley, M. R. 1951. Seeds of the Cruciferae of northeastern North America. Amer. Midl. Naturalist 46: 1–81.

Schulz, O. E. 1936. Cruciferae. Pp. 227–658 *in* A. Engler & H. Harms (editors), Die natürlichen Pflanzenfamilien, Vol. 17B. Verlag von Wilhelm Engelmann, Leipzig.

Simmons, M. P. & H. Ochoterena. 2000. Gaps as characters in sequence-based phylogenetic analyses. Syst. Biol. 49: 369–381.

Swofford, D. L. 1998. PAUP*: Phylogenetic Analysis Using Parsimony, Vers. 4.0. Sinauer, Sunderland, Massachusetts.

Sullivan, J. 1996. Combining data with different distributions of among-site variation. Syst. Biol. 45: 375–380.

Taberlet, P., L. Gielly, G. Pauton & J. Bouvet. 1991. Universal primers for amplification of three non-coding regions of chloroplast DNA. Pl. Molec. Biol. 17: 1105–1109.

Tan, Z. M., Z. Q. Zhang, Y. Zhao & S. D. Zhou. 1999. Cruciferae. Pp. 1–181 *in* B. G. Li (editor), Flora Sichuanica, Vol. 14. Sichuan Nationality Press, Chengdu.

Thompson, J. D., T. J. Gibson, F. Plewniak, F. Eanmougin & D. G. Higgins. 1997. The ClustalX Windows interface: Flexible strategies for multiple sequence alignment aided by quality analysis tools. Nucl. Acids Res. 24: 4876–4882.

Warwick, S. I., I. A. Al-Shehbaz, C. Sauder, J. G. Harris & M. Koch. 2004. Phylogeny of *Braya* and *Neotorularia* (Brassicaceae) based on nuclear ribosomal internal transcribed spacer and chloroplast *trn*L intron sequences. Canad. J. Bot. 82: 376–392.

———, C. A. Sauder, I. A. Al-Shehbaz & F. Jacquemoud. 2007. Phylogenetic relationships in the tribes Anchonieae, Chorisporeae, Euclidieae, and Hesperideae (Brassicaceae) based on nuclear ribosomal ITS DNA sequences. Ann. Missouri Bot. Gard. 94: 56–78.

White, T. J., T. Bruns, S. Lee & J. W. Taylor. 1990. Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. Pp. 315–322 *in* M. A. Innis, D. H. Gelfand, J. J. Sninsky & T. J. White (editors), PCR Protocols: A Guide to Methods and Application. Academic Press, New York.

Yue, J. P., Z. J. Gu, I. A. Al-Shehbaz & H. Sun. 2004. Cytological studies on the Sino-Himalayan endemic *Solms-Laubachia* Muschler and two related genera (Brassicaceae). Bot. J. Linn. Soc. 145: 77–86.

———, H. Sun, I. A. Al-Shehbaz & J. H. Li. 2006. Support for an expanded *Solms-laubachia* (Brassicaceae): Evidence from sequences of chloroplast and nuclear genes. Ann. Missouri Bot. Gard. 93: 402–411.